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Information Exchange Requirements for Networked Underwater Warfare

Marcel Lefrançois

Defence R&D Canada – Atlantic

Technical Memorandum

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Abstract

It is widely assumed that sharing information between individual platforms using tactical networks will improve the accuracy of the Common Operating Picture (COP). This interest is based on the belief that task group effectiveness increases with the amount of shared information. This is true only if the information exchange requirements are carefully considered. Not only is the correct information required at the right time but the weight in importance of one information type versus another must be considered when allocating communication resources. The scope here has been limited to the formation of the Underwater Picture in an Anti-Submarine Warfare (ASW) scenario.

The information content requirement is addressed with the definition of twelve types of information, each described in detail. This information contains tactical command and control type information as well as sensor information used to process sonar signals and form the COP. The detail goes beyond the present command and control data available in existing communications like Link 11 and OTH Gold. Instead, an IP based network with information push-pull capability is envisioned. This network will operate with a limited bandwidth in Defence R&D Canada – Atlantic's Networked Underwater Warfare Technology Demonstration Project. So, rather than transmitting everything, careful choices must be made and priorities and urgency must be considered. An analysis of an ASW operation is presented showing the relative importance of the data and how the importance changes with the phase of the operation.

Résumé

On considère généralement que le partage d'informations entre les plates-formes individuelles au moyen de réseaux tactiques augmentera la précision de la situation opérationnelle commune (COP). On croit en effet que l'efficacité du groupe opérationnel augmente en fonction de la quantité d'informations partagées. Cela n'est pourtant vrai que si les besoins d'échange d'informations sont soigneusement étudiés. Quand on attribue les ressources de communication, il faut non seulement avoir au bon moment les informations dont on a exactement besoin mais aussi déterminer si un type d'informations est plus important qu'un autre. La portée de l'étude s'est limitée à la création de la situation sous-marine dans un scénario de guerre anti-sous-marine (GASM).

Le besoin relatif au contenu informatif est précisé par la définition de douze types d'informations, chacun décrit en détail. Cette information contient de l'information sur le type de commandement et control tactiques et de l'information sur les capteurs servant à traiter des signaux sonar et à créer la COP. Les détails vont au-delà des données sur le commandement et contrôle actuel qui sont disponibles dans les communications courantes telles que Link 11 et OTH Gold. On envisage plutôt un réseau IP doté de la technologie du pousser-tirer. Ce réseau fonctionnera avec une largeur de bande limitée dans le projet de démonstration de technologie de guerre sous-marine en réseau réalisé par R & D pour la défense Canada - Atlantique. Ainsi, au lieu de transférer tout, on doit soigneusement faire des choix et étudier les priorités et les urgences. Une analyse d'une opération de GASM est fournie, démontrant l'importance relative des données et la manière dont l'importance change suivant la phase de l'opération.

Executive Summary

Introduction

It is widely assumed that sharing information between individual platforms using tactical networks will improve the accuracy of the Common Operating Picture (COP). This interest is based on the belief that task group effectiveness increases with the amount of shared information. This is true only if the information exchange requirements are carefully considered. Not only is the correct information required at the right time but the weight in importance of one information type versus another must be considered when allocating communication resources. The scope here has been limited to the formation of the Underwater Picture in an Anti-Submarine Warfare (ASW) scenario.

Results

The information content requirement is addressed with the definition of twelve types of information:

1. Environmental Data
2. Receiver Information
3. Source Information
4. Echo Repeater Information
5. Ping Information
6. Feature Data
7. Main Blast Data
8. Contact Data
9. Track Data
10. Sonograms
11. Email and Chat Messages
12. Tactical Information

each type is described in detail and then placed in priority importance for exchange during an ASW operation. These priorities change depending on the phase of the operation and on the capabilities and interest of participating platforms.

Significance

The information requirements presented here are required for the implementation of information sharing over a tactical information network in the Networked Underwater Warfare (NUW) Technology Demonstration Project (TDP). The details of each information type goes beyond the present command and control data available in existing communications like Link 11 and OTH Gold. The detail reaches down to the sensor level. It is expected that the information and study of the priorities presented here will help in future developments in information sharing for the Navy.

Future Plans

The information presented here is a framework of requirements for moving forward and implementation into some trials. These future experiments will refine many of the concepts presented here. The refinements are expected to be mostly in resetting information transmission priorities with a few adjustments to the underlying information content. These will be reported as the NUW TDP proceeds.

Lefrancois, M.E., 2004, Information Exchange Requirements for Networked Underwater Warfare, DRDC Atlantic TM 2004-168, Defence R&D Canada – Atlantic

Sommaire

Introduction

On considère généralement que le partage d'informations entre les plates-formes individuelles au moyen de réseaux tactiques augmentera la précision de la situation opérationnelle commune (COP). On croit en effet que l'efficacité du groupe de travail augmente en fonction de la quantité d'informations partagées. Cela n'est pourtant vrai que si les besoins d'échange d'informations sont soigneusement étudiés. Quand on attribue les ressources de communication, il faut non seulement avoir au bon moment les informations dont on a exactement besoin mais aussi déterminer si un type d'informations est plus important qu'un autre. La portée de l'étude s'est limitée à la création de la situation sous-marine dans un scénario de guerre anti-sous-marine (GASM).

Résultats

Le besoin relatif au contenu informatif est précisé par la définition de douze types d'informations :

1. Données environnementales
2. Informations destinataires
3. Informations des sources
4. Informations du répéteur d'écho
5. Impulsions de sonar
6. Données de l'élément
7. Données transmises directement du sonar source au réseau
8. Données de contact
9. Données de poursuite
10. Sonogrammes
11. Courriel et messages de conversation
12. Informations tactiques

Chaque type est décrit en détail puis placé par ordre d'importance en vue d'un échange pendant une opération de GASM. Les priorités changent selon la phase de l'opération et les capacités et intérêts des plates-formes participantes.

Portée

Les besoins d'informations présentés dans cette étude sont nécessaires à l'application du partage d'informations sur un réseau d'informations tactique dans le projet de démonstration de technologies (PDT) Guerre sous-marine en réseau (GSR). Les détails de chaque type d'informations vont au-delà des données sur le commandement et contrôle actuel qui sont disponibles dans les communications courantes telles que Link II et OTH Gold. Ils atteignent le niveau des capteurs. On s'attend à ce que l'information et l'étude des priorités présentées dans cette étude contribuent aux développements futurs du partage d'informations dans la Marine.

Plans pour l'avenir

Les informations présentées dans cette étude constituent un cadre des besoins, aidant à aller de l'avant et servant à effectuer certains essais. Ces futures expériences mettront au point beaucoup des concepts présentés ici. On estime que les mises au point consisteront généralement à rétablir les priorités de transmission d'informations avec quelques ajustements au contenu de l'information sous-jacente. Ces travaux feront l'objet d'un rapport à mesure que le PDT GSR avance.

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1. Background and Overview

Naval operations often require more than one platform[†] forming a task group to work together towards a common goal. A great deal of effectiveness can be achieved through prior planning, like a football coach does before the game. However, the exchange of information during an operation can greatly enhance the group's effectiveness and allow it to act faster so that it can achieve its goals before the opposing units can respond.

Currently, there is much interest in sharing information between individual platforms using tactical communication networks. This interest is based on the belief that task group effectiveness increases with the amount of shared information. This can be achieved only if the data exchange requirements are carefully considered. Data sharing is most effective when just the right information to assist the operator is exchanged. Increasing the quantity of data will not necessarily assist the operator and may generate information overload.

The intent is to share enough information to have all the networked platforms forming a tightly integrated team having a Common Operating Picture (COP). Presently, sharing and fusing the information between platforms is hampered by a lack of integration standards and limited available bandwidth.

The Networked Underwater Warfare (NUW) Technology Demonstration Project (TDP), being carried out at Defence R&D Canada – Atlantic, will share information and improve situational awareness by connecting platforms via an IP (Internet Protocol) based network. This will be done using a shared bandwidth of approximately 64 kilobits/second. This communication rate cannot support continuous data exchange of all collected data from any of the networked platforms. Therefore, intelligent choices must be made for selecting what information to share. This selection depends on the phase of the operation and the types and quantities of data available.

The work presented here addresses the question of what information to share between a Maritime Patrol Aircraft (MPA) monitoring a deployed sonobuoy field and a surface ship towing a line array sonar engaged in an Anti-Submarine Warfare (ASW) operation. This is followed by a discussion on information exchange priorities and issues for different phases of the ASW operation.

1.1 Networked Underwater Warfare TDP

The NUW TDP will demonstrate data exchange between tactical systems located on separate platforms [1]. The goal of the NUW TDP is to demonstrate that effectiveness in conducting UnderWater Warfare (UWW) increases when multiple platforms share information via a common networked infrastructure[2]. This will be demonstrated in an

[†] Platform here refers to a ship, submarine, aircraft or other unit with capability.

ASW operation as shown in figure 1. In this scenario, the platforms will demonstrate that sharing information improves the generation of the UWW component of the COP. There have been studies on the effectiveness of sharing information between similar platforms, the NUW TDP will investigate the value added by exchanging information between dissimilar platforms - namely a surface ship and an aircraft. The principal aim is to enhance the formation of the tactical picture. This means faster compilation of the COP with higher confidence in its accuracy

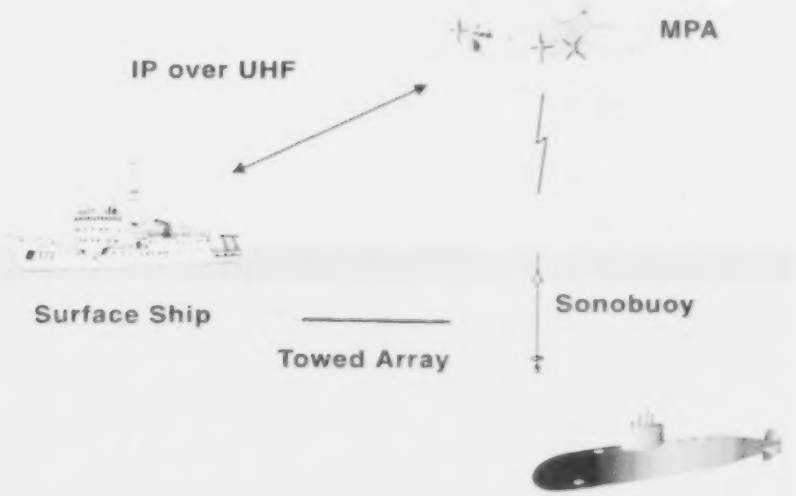

Figure 1. NUW ASW Demonstration Scenario

NUW is built on two previous demonstrators for sonar processing and data management. The Towed Integrated Active Passive Sonar (TIAPS) [3] system dry end processing component, called the System Test Bed (STB)†, will be employed on the surface ship. The system employed on the MPA is the Integrated Multistatic Passive Active Concept Test Bed (IMPACT) [4]. Both systems process acoustic data and manage the sonar information. Each also has data association and analysis tools to assist the operator in finding, localizing, and classifying potential targets. The difference between the two systems is that IMPACT operates on data from a deployed sonobuoy field while the System Test Bed handles data from towed line arrays. The focus of both systems has been the single platform perspective. The NUW project will enlarge this perspective to multiple platforms combining data in a tightly networked environment to form a single team performing ASW.

† Formerly called the Sonar Test Bed

Formation of a team of platforms requires merging inorganic information (from off platform sources) with organic data (inherent to the platform). There has been some work considering information sharing issues from a command and control perspective [5]. There also exist data transmission and storage standards for multistatic information [6][7]. Even though these standards and guidelines offer a path towards a uniform data exchange standard, the development of an accepted integrated standard encompassing command level data, sensor information, transmission and format standards, and a common definition has not yet been achieved.

The work here is a first step towards the development of an information integration framework that will be applied to the NUW TDP. This first step identifies the sonar information required and some of the issues in exchanging the information for the generation of the underwater portion of the COP.

1.2 Available Data

An initial look at available data transmissions between platforms suggests that Link 11, OTH Gold and the like could be used to exchange information. However, their formats are strict and limited and do not include enough detail to support sophisticated sonar data fusion, tracking schemes and localization. There are many other communications channels and formats available to IMPACT and the System Test Bed, but all have similar limitations.

NUW will use an IP network and can transmit data structures of its own design and choosing. There is an opportunity here to establish an integrated standard since there are no accepted standards[†]. Therefore, rather than deriving the sonar information required from communication standards the derivation should be based on what data each system handles and stores and what is required that would enhance the task group's capability in conducting an ASW operation.

Since both IMPACT and the System Test Bed are working systems and have been used in at sea trials they contain most of the desired data within their respected databases. Both IMPACT and the System Test Bed use the same data server components for storage and access of all sonar information. This commonality means that many of the data types are similar with only minor differences in representation. Any differences can be easily overcome by extending the software or the database components to accommodate the variation.

For the purpose of deciding what information to share between platforms it can be assumed that all the required sonar data will be in the data server.

[†] There are efforts being pursued like the NATO LC2IEDM which are moving towards adoption in NATO however these standards are often focussed at a command and control level or are focussed on land forces rather than a maritime environment.

1.3 Communications link

In NUW the data exchange will be done via an IP network over UHF radio. Ideally, information exchange would take place using a system with an infinite bandwidth. This would allow all information to be transmitted and shared between platforms. The reality is that a communication rate of approximately 64 kilobits/second will be available in the NUW TDP [8]. This communication rate cannot support the continuous exchange of all information nor even the continuous exchange of a single beam of acoustic sonar data. Information must be distilled down to meaningful packets before transmission. In addition, intelligent choices must be made for selecting the data for exchange. The selection will change with available bandwidth and operational phase.

1.4 Networks and Network-Centric Warfare

The NUW TDP will use *networked* platforms connected via a *network* to perform *network-centric warfare*. Since the NUW TDP relies on the formation of a team of platforms communicating via a network the distinction between *networked*, *network* and *network-centric warfare* is clarified below.

A *network* is defined as [9] a system of computers interconnected by telephone wires or other means (like UHF radio) in order to share information.

In the context of NUW, *networked* is a means [9] to interact or engage in informal communication with others for mutual assistance or support. Such is the case when users are able to select methods of information access such as what one is interested in and whether information is pushed or pulled over the network.

Network-centric warfare is the linking of platforms into one shared-awareness network in order to obtain information superiority, get inside the opponent's decision cycle, and end conflict quickly.[10]

1.5 Assumptions and Limitations

As already indicated in section 1.2, the data for exchange has been chosen to aid the platforms in conducting an ASW operation. As such, the data list presented in the next chapter is generally applicable to information sharing to form the UWW portion of the COP. The list has not been constrained by the application of specific communication formats nor by what is currently contained in existing systems.

As such, the sonar systems employed are assumed capable of providing the acoustic information required such as source and receiver characteristics, acoustic propagation information, raw data as well as higher level processed and fused data that can be used to form contacts and tracks. There should also exist a suite of collaboration tools like email and command information in the form of tactical messages. Any data structure that is not currently existing can be implemented into the IMPACT and System Test Bed for evaluation when required.

The aim here is to describe the required information not the format; and to set out what information is needed for an effective team sharing data and collaborating in the fusion of the information. It is assumed that the sonar processing software can be upgraded to fill any missing information gaps.

At first examination the quantity of information may seem large. However, it is not expected that all information elements will be transmitted every time.

1.6 Information to be Exchanged

The information to be exchanged falls into 12 broad categories:

1. Environmental Data
2. Receiver Information
3. Source Information
4. Echo Repeater Information
5. Ping Information
6. Feature Data
7. Main Blast Data
8. Contact Data
9. Track Data
10. Sonograms
11. Email and Chat Messages
12. Tactical Information

Each information type is described in the following sections with a breakdown of the contained information components. The priority and sharing modes are given in the context of an ASW operation.

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2. Information Exchange

The ultimate information exchange within a task group is achieved by forming a common database that is replicated across all systems. Thus, the entire data set is available to the operators and the signal processing systems on all platforms. Utilizing the same data and processing algorithms along with a common understanding of what each data item is, each individual platform can obtain the same information and thus generate the same operational picture. In which case, they would all by design, automatically generate the same Common Operating Picture (COP)†.

However, with a limited communication bandwidth not all of the data from one platform can be replicated for use on another platform. This means intelligent choices on what to transfer must be made. The transferred data must be meaningful and capable of conveying enough information to construct a common understanding of the tactical situation. In addition it is desirable to receive information that when combined with the existing information on the platform will form new information or knowledge of the environment that could not have been obtained from the single platform alone. Indications from previous work indicates that this can be accomplished by exchanging a modest amount of data. [11] [12].

For the NUW TDP, rather than the full set of data being continuously transmitted a selection will be transmitted. Some information will be automatically transmitted while some others require only occasional updates and the remaining types will be transmitted only on demand. In addition, the type of information and quantity will vary with the task group's activity. The information types to be exchanged in NUW fall into the following categories:

1. Environmental Data
2. Receiver Information
3. Source Information
4. Echo Repeater Information
5. Ping Information
6. Feature Data
7. Main Blast Data
8. Contact Data
9. Track Data
10. Sonograms
11. Email and Chat Messages
12. Tactical Information

The make-up each information type is described below. Common to each is the information source; either through a name or an ID tag. This is required to reduce the size of transmitted data and prevent data incest from occurring during fusion operations. For

† The COP is generated by the task group for the local operating area. The COP data adds to the compilation of the Recognized Maritime Picture (RMP) which is generated at a Maritime Security Operations Centre (MSOC) to cover the entire ocean.

example the first transmission of Source Information contains a full description of the source including a unique ID. The next transmission may update only the location and contain only the ID and new coordinates. The ID could be a single identifier or broken into components to identify country affiliation of platform, hull number or name and sonar processing system or operator. A single reference number is more compact but requires agreements before sharing to prevent duplicate ID assignments such as could occur if single reference IDs are used.

Information exchange requires common understanding of the data between platforms. Without identical definitions, the ability to generate the common operating picture will be compromised. This common understanding can be imposed at design/implementation time by introducing a common database and replication capability to translate the information between systems. The list of information requirements below will help facilitate the first step in the process; creation of a common understanding of the shared information.

2.1 Information Types

The different information types for sharing are described below. The list is complete only in that it contains the information and its components for implementation in the NUW TDP. It is expected that future work and testing will cause the list to be revised. The list consists of information items. The specific data structures for internal coding are best left to the software engineer during implementation. The data structure for transmission between platforms needs to be agreed upon and will be addressed in a separate document. The intent here is to describe the requirement and forge a way ahead.

This list started as a proposal presented to a group of sonar experts for discussion. The resulting list from the discussions is given in appendix A. During the preparation of this document it was realized that a few information components were missing or needed expansion. Two new information types were added to the list, namely Main Blast Data and Echo Repeater Information. The entire list of required information is presented below.

2.1.1 Environmental Data

Environmental data contains information on the acoustic conditions such as sound speed profiles, convergence zones, and propagation path predictions. Mission data consists of two parts. The first is the data loaded prior to the mission such as historic environmental databases. The second part is data acquired during a mission. The prior data load is assumed to be common to all platforms while the newly acquired data will be shared. Sharing can take two forms: sensor data and acoustic modelling. These are given below.

2.1.1.1 Environmental Sensor Data

Environmental sensor data is obtained from sensors such as eXpendible Bathy-Thermographs (XBT). This includes identification of the type of sensor, where the data was taken and when, what was measured, and the values. For many measurements a simple array of measured values with depth will suffice. However in the case of ambient noise spectra, multiple frequencies or a spectra will need to be provided at each depth. Optional fields are also required if a processed value is passed such as the average value of sound used for sonar signal processing. The environmental sensor data is made up of:

1. Sensor ID
2. Sensor Name
3. Platform ID (sensor owner)
4. Data Type (Temperature, Salinity, Sound Speed)
5. Time data was taken
6. Location of Data Sample (latitude/longitude/depth)
7. Measurement units (e.g. °C or m/second)
8. Data Profile with depth points
9. Ambient noise spectrum (depth and frequency points)
10. Average data value used for processing
11. Depth of average value

Environmental sensor data may also be obtained through the sonar receiver. For example, transmission loss estimates may be obtained in bistatic operations if the source and receiver are calibrated and the positions of each are known. Sharing this information may help validate the sonar prediction modelling information and may lead to changes in ping waveforms and amplitudes in order to maximize detections.

2.1.1.2 Modelling Information

Acoustic modelling is very useful for tuning the sonar characteristics and understanding the sonar data. Modelling Information encompasses two types of shared environmental data. The output of performance/prediction runs (for example from AESS) and the input files used to configure the processing run. The ability to transfer information from the prediction engine to the operators is to be implemented along with the ability to send configuration files for comparison and requesting runs. Version information for the model is also required to help operators verify the prediction models used when comparing outputs. The components for modelling information are:

1. Prediction engine and version used or to use
2. Platform ID (Prediction engine owner)
3. Output from prediction engine like AESS
   a. ID for run (i.e. a run number)
   b. Time of run
   c. Output Data

4. Configuration files for processing (may include an ID tag for future reference)

The prediction engine and version should be transmitted with each data set to ensure that the data and processing engine/version are attached to the data and should also include the originating platform/system. The configuration file information should be attached for future reference (either the entire file or a reference ID) when receiving prediction output.

In NUW, environmental information sharing should be limited to requests for model output and new sensor data. Potentially, it is possible to also send configuration files for starting new prediction runs. However, this requires a trust and sharing of resources which may be difficult to achieve†. Requests for prediction runs and the passing of a configuration files for these purposes should be done via Email.

2.1.2 Receiver Information

Receiver information describes the characteristics of acoustic sensors receiving the sonar signal. The contained information is required for proper interpretation of the sonar signals and for tactical information such as what the sensor is capable of and how long it is expected to be operational. It is most likely that the key information will be transmitted only once and thereafter only the altered information will be shared such as location or remaining life.

There are two parts to receiver information. One part is common to all receivers and the second part contains specialized data characteristic to a particular receiver. The common part is given below along with two specializations: one for towed arrays and the other for sonobuoys.

2.1.2.1 Receiver Information - Common

The following information is common to all types of sensors. This includes identifiers and description plus the time the data was taken along with the receiver's speed, heading, and orientation.

1. Sensor ID
2. Sensor Name
3. Platform ID (sensor owner)
4. Sensor Class (array or buoy)
5. Sensor Type (specific array or buoy type)

† This may be difficult to achieve both policy-wise and technically. First, it may be policy that secure computer systems may not be allowed to service off platform requests for CPU resources. And secondly, the technical challenge of scheduling resources when many different requests are made to run the prediction engine. These runs typically take a long time and are computer intensive so many requests at once may introduce lengthy delays in obtaining the desired run data, which would greatly reduce the usefulness of the information.

6. Time
7. Operating Status
8. Latitude and Longitude
9. Sensor Depth
10. Sensor Speed
11. Sensor Heading (direction of motion)
12. Sensor Heading (orientation of beams - note the sensor may not be pointed in the same direction as the motion)
13. Sensor Gain (AGC (Automatic Gain Control) mode or gain setting)
14. Sensor Sensitivity (Possibly an array of gain versus frequency)
15. Calibration Status (absolute, relative, or not calibrated)

2.1.2.2 Receiver Information - Towed Array

Towed arrays offer a number of beams or directions to pick up sonar signals on. Normally, the quantities of interest are the scope, or distance behind the towing platform, and the beam-formed data. There is little need to get into the raw data from the hydrophones since the initial beamforming and processing are performed by the platform that owns the array. Sharing raw data means that the processing is being duplicated within the task group using resources that are better focussed elsewhere. The information components are as follows:

1. Scope
2. Number of Beams
3. Beam Angles with respect to the forward direction of the array
4. Left/Right Ambiguity Resolution Flag (1 = yes the array can resolve which side of the array a return is from, 0 = no this cannot be resolved.

2.1.2.3 Receiver Information - Sonobuoy

Sonobuoys are drifting hydrophones that radio the received acoustic signal back to a receiving platform. There are recording standards for sonbuoy information[6] [13]. However the recording standard incorporates many other aspects and is a fixed packet size, thus the exchange of only changed information to save bandwidth is not possible. The information required by another platform specific to the sonobuoy characteristics are:

1. RF Channel
2. Remaining Life
3. Drift Status
4. Splash point with unknown, low or good accuracy or DMS plot stabilization info
5. Buoy Mode (if applicable)
6. RF channel mode (transmitting/not transmitting)
7. Method of position determination

2.1.3 Source Information

Source information contains information on acoustic sources. Most often this is a source which projects pings into the water however it may be possible to describe a source of opportunity (like a passing tanker). The information contained here only describes the source and its location. The acoustic information is given in the Ping information component discussed in the next section (2.1.5). Source information contains:

1. Source ID
2. Source Name
3. Platform ID (source owner)
4. Source Type
5. Time
6. Location (Latitude and Longitude)
7. Source Depth
8. Source Speed
9. Source Heading
10. Source Beam Heading and Vertical Steering Direction
11. Source Level (peak power)
12. Source Level Units (dB, μPa, etc.)
13. Calibration Status (absolute, relative, not calibrated)

2.1.4 Echo Repeater Information

Although of limited tactical significance echo repeater functionality can greatly enhance trials and testing capability. Echo repeaters are often used to compare sonar echoes from a target to a known signal emitted from the echo repeater mounted on the target. An echo repeater is a source with a known time delay and acoustic signature, hence the information to describe the echo repeater contains all the information for a source plus a delay time and waveform description. The information is given by:

1. Echo Repeater ID
2. Echo Repeater Name
3. Platform ID (echo repeater owner)
4. Echo Repeater Type
5. Time
6. Location (Latitude and Longitude)
7. Echo Repeater Depth
8. Echo Repeater Speed
9. Echo Repeater Heading
10. Echo Repeater Beam Heading and Vertical Steering Direction
11. Echo Repeater Level (peak power)
12. Echo Repeater Level Units (dB, μPa, etc.)
13. Calibration Status (absolute, relative, not calibrated)
14. Wavetrain ID(s) the echo repeater is triggered off of
15. Wavetrain ID(s) the echo repeater is set to respond with (corresponding to the list the unit triggers off of)

16. Time delay between received wavetrain and emission

The echo schedule or emission would be obtained from a Ping Information structure as described in the next section.

2.1.5 Ping Information

Ping information describes the characteristics of acoustic signals projected into the water. The simplest ping is a single waveform like CW (Continuous Wave) or FM (Frequency Modulated). A waveform is characterized by frequency, duration and amplitude. A ping may be made up of a series of waveforms also called a wavetrain. A wavetrain is composed of a set of waveforms each one with a time offset from the start of the wavetrain.

Besides the waveform information, active sonar data processing requires prior knowledge of the ping characteristics in order to analyze received sonar signals and pick the projected ping out from the background noise. In the event that the waveform has not been successfully projected into the water the processing may fail. In these cases knowledge that the ping failed may be valuable. Thus, there are three types of ping information:

1. Waveform/Wavetrain Data
2. Next Ping Information
3. Ping Status

2.1.5.1 Waveform/Wavetrain Data:

The first ping information type is the wavetrain. This is composed of a wavetrain description followed by a description of each of the constituent waveforms. This must be done with a common understanding of the waveform types so that characteristic frequencies and descriptions construct identical waveforms.

Since pings are often repeated it may be possible to build up a data base of waveform/wavetrain types and then reference the waveform by its ID. In doing so, it may be best to exchange ID's and if it does not exist in the platform database then automatically generate a request for the detailed information to the source platform. Automatic requests are used since the platform databases may have started at different times, such as the joining of a platform to a task group already in operation. Obviously, in these cases the joining platform would not have obtained the ping information from the first broadcast and must obtain it by requesting the information.

Waveform/Wavetrain data is as follows:

1. Wavetrain ID
2. Wavetrain Name
3. Wavetrain Source ID
4. Wavetrain Start Time

5. Number of Waveforms Forming the Wavetrain
6. For each Waveform
   a. Waveform ID
   b. Waveform type (e.g. CW, FM)
   c. Envelope type (e.g. Hamming)
   d. Duration of waveform
   e. Offset Time from start of wavetrain
   f. Amplitude or source level
   g. Source level reference (absolute/relative)
   h. Characteristic Frequency 1 (e.g. Centre Frequency)
   i. Characteristic Frequency 2 (e.g. Modulation Frequency)
   j. Characteristic Frequency 3 (e.g. Bandwidth)
   k. Sampled Waveform (To handle other waveforms like Costas)

Note that the use of the characteristic frequencies can change with waveform type and must be understood prior to deployment†.

2.1.5.2 Next Ping Information

Next ping information is used to notify the other platform(s) what the next ping is and when it will occur. Advance notice of a ping is required in bistatic sonar processing to setup the proper matched filter to sense the ping and to ensure proper input to the processing calculations such as for localizing a target. The components of next ping information are:

1. Event number (each ping has a unique number for identification)
2. Ping Source ID
3. Next Wavetrain (either a Waveform/Wavetrain information structure or a reference Wavetrain ID)
4. Start Time for Wavetrain
5. Wavetrain Rate (period between wavetrains if applicable)
6. Last ping in sequence notification as a notification to end processing or not to expect further pings.

The same structure could be used to send ping requests however this requires a negotiation or trust between platforms for automatic handling. This is outside the present scope of NUW however requests could be made using email messages and attaching the next ping information structure to the message.

2.1.5.3 Ping Status

The ping status is sent after transmission to indicate success or failure. The structure contains the event number to identify the ping and a success or failure flag. Since more than one source may be operating the Source ID is

† If the capability exists it may be possible in the future to email a description of the waveform type (governing equations) and incorporate it into the sonar processing system. For now the default is to send a sampled waveform file.

included. Measured source level may be provided. One benefit of the source level is the potential to calculate environmental parameters like transmission loss.

1. Source ID
2. Event Number
3. Success or Failure Flag
4. Source Level Measured (peak)

An extension of this is to define what success means. Is success providing the correct wavetrain to the source driving electronics or is it that the correct wavetrain has been projected into the water? These distinctions could be embedded in the Success/Failure flag.

Another extension is to use the success/failure flag to indicate that a wavetrain has been successfully put in the water but it was the wrong one. The Event number could then be used to point to the correct wavetrain. The interested platforms could then send a request to the source platform for the properties based event number.

2.1.6 Feature Data

Features are distinct anomalous events or characteristics that produce a positive signal excess from the signal processing. Features are the lowest level of data the operator interacts with through either manual or automated tools. A feature contains enough information to allow association with other entities.[14]

Feature data may be exchanged as bandwidth is available and it is requested. The potential benefit of exchanging feature data is great but the information load may be large since the data is close to the sensor and includes sonar clutter, events, and characteristics that are unrelated to platform detection and tracking. Despite this, the use of feature data from other platforms will allow for new information to be formed that otherwise could not be deduced from single platform data.

There are two parts to feature data: a part that is common to both active and passive features and a specific component for either active or passive data. These are described below.

2.1.6.1 Feature Data - Common

The common feature data contains a unique identifier in order to keep track of its use when forming feature sets, contacts, and tracks. Similarly, if the feature has been placed fused into a contact or track then a reference value should be set to identify the association. To prevent data incest the originating sensor and platform should also be provided. The time the feature was formed or detected should also be provided since timeliness of the data can affect its use. Users can place commands to associate, assign, move, or erase features and these actions should be noted along with the current status of the feature (unas-

signed, assigned, locked, lost, etc.). This list of common values for feature data is summarized as:

1. Feature ID
2. Contact or Master Track ID associated with (if applicable)
3. Sensor ID (can get sensor speed heading etc. using this)
4. Platform ID
5. Time
6. Command (unassign, assign, set name, move, start, drop, cut, erase)
7. Status (unassigned, assigned, acquiring, locked, lost)

2.1.6.2 *Feature Data - Passive*

Passive features contain information on which direction the acoustic signal was received on along with variance and motion values. If estimates are possible (Such as by using TMA algorithms) then speed and position information is also provided. Parameters to describe the area of uncertainty or the lines along which the target could be may also be provided (such as hyperbolas which result from time of arrival calculations at 2 sonobuoys or ellipses which occur in bistatic sonar systems). Data items which describe the nature of the acoustic signal are also provided.

Passive sonar feature data contains:

1. Bearing
2. Bearing Rate
3. Bearing Variance
4. Bearing Rate Variance
5. Range
6. Range Rate
7. Range Variance
8. Range Rate Variance
9. Latitude estimate of target
10. Longitude estimate of target
11. Speed of Target
12. Speed Variance of Target
13. Area Of Uncertainty (AOU) - this may require parameters to describe elliptical areas or hyperbolas if applicable
14. Frequency
15. Frequency Variance
16. Frequency Rate
17. Frequency Rate Variance
18. Frequency Jitter (used in [11])
19. Frequency Wander (used in [11])
20. Amplitude
21. Amplitude Variance
22. Signal Duration
23. Background level (noise)

2.1.6.3 *Feature Data - Active*

Active features contain information on the direction and strength a reflected ping has been received on (i.e. not the main blast from the source but all other returns). Active feature data includes the source ID and event number so that the originator and ping are uniquely identified. Location and speed estimates of the target are also given along with some of the conditions and processing parameters. Active feature data consists of the following:

1. Source ID (the source emitting the ping)
2. Event Number (indicating which ping was used)
3. Bearing
4. Range
5. Speed/Direction estimates of target
6. Amplitude of return signal (see below for description)
7. Background level (reverberation estimate)
8. Processing parameters (e.g. Number of bounces, windowing etc.)
9. Parameters to describe elliptical areas or hyperbolas if applicable (such as time of main blast arrival and return signal in multistatic sonar)

A description of the amplitude and background levels is similar to other works in fusing multistatic data[15]. For the purposes here, there are 3 parts to the amplitude and background levels used in fusing active contacts into tracks:

1. Contact's maximum peak power level (dB)
2. Contact's mean power baricenter (dB)
3. Contact cluster descriptions (for example)
   a. cluster size (area)
   b. cluster energy (sum above a threshold)

2.1.7 Main Blast Information

The main blast is the acoustic signal arriving at the sensor directly from the source without reflection off any other surface or target. Main blast information may be used in tracking, interpretation and environmental assessments. Main blast information is similar to active feature data and in some cases could be treated as a feature but it is given its own type since its information content is handled differently. The information contained in a main blast is as follows:

1. Main Blast ID (for future reference)
2. Source ID that emitted acoustic pulse (gives location and speed information)
3. Receiver ID that received the main blast (Location, speed and ownership information)
4. Ping Event Number that resulted in Main Blast
5. Time Main Blast was received
6. Beam the blast was received on
7. Received Energy contained in Main Blast
8. Energy Measurement Accuracy
9. Energy Measurement Units (Joules, Pa, dB)

10. Peak Amplitude of Main Blast
11. Units of Peak Amplitude (Pa or dB)
12. Calibration status (absolute, relative, or not calibrated)

Main blast information is used to calculate possible target positions in bistatic sonar and can also be used to calculate transmission losses to help tune the sonar parameters.

2.1.8 Contact Data

A contact is one or more features that have a high probability of being caused by a real world object; in the context of sonar processing, this normally implies a maritime platform. The designation of a contact involves a decision by an operator or automatic process, i.e., the confidence level that the source creating the features is a platform has risen above some threshold.[14]

Contacts contain data derived from other sources (typically feature data). Hence there is no need to distinguish between active and passive contacts since a contact can be composed of both and contains references to the features that it contains. The contact contains information on where the information originated from, unique contact identifiers, and operator guesses on what the target is, its status and whether it is hostile. Location estimates are also provided. The underlying features may not all be in agreement on location and the location estimate of the contact could be formed by a processing algorithm of the feature data (for example a simple average). Contact data contains:

1. Platform ID (data source/owner)
2. Operator ID (data source/owner)
3. Name (unique or on screen name of contact)
4. Contact ID (unique numeric identifier)
5. List of Feature and Contact ID's that make up Contact
6. Master Contact/Track ID (if associated)
7. Classification (unknown, SUB,DDG,FFG,WAR, etc.)
8. Confidence Level (POSSUB, PROBSUB, CERTSUB)
9. Acceptance or Team Confidence Level
10. Time
11. Time of Contact creation or notification
12. Threat (friendly, hostile, neutral)
13. Command (add, move, delete etc.)
14. Status (assigned, acquired, locked, lost)
15. Range/Bearing/Latitude/Longitude/Depth Estimates
16. Speed/Heading Estimates
17. Area of Uncertainty (AOU)

Note that there are two different confidence levels, the first is the Confidence Level that would be used once the contact is placed in the Common Operating Picture (COP). The second, Acceptance or Team Confidence, is used by the team of operators and tactical

personnel during discussions before placing the contact into the COP to gauge overall acceptance of the contact.

2.1.9 Track Data

A Track is a sequence of features or contacts whereby the system or operator can estimate kinematic attributes of the real world object, which can include the direction to the object, its position, its course, and/or its speed.[14]

Track data contains the same elements as Contacts. In addition Track data includes data quality information and tracking information for estimating locations. The contents are as follows:

1. Platform ID (data source/owner)
2. Operator ID (data source/owner)
3. Name (unique or on screen name of track)
4. Track ID (unique numeric identifier
5. List of Feature, Contacts and Tracks that make up Track
6. Master Track ID (if associated)
7. Classification (unknown, SUB, DDG, FFG, WAR, etc.)
8. Battle Space (Surface/Subsurface)
9. Mode (transiting, maneuvering, unknown)
10. Time
11. Time of Track Creation
12. Threat (unknown, friendly, hostile)
13. Command (unassign, assign, extrapolate, set speed etc., delete, move, localize)
14. Status (unassign, assign, extrapolate, interpolate, localize)
15. Longitude/Latitude/Depth/Latitude Error/Longitude Error/Depth Error
16. Speed/Heading Estimates
17. DQI Level (Data Quality Index – indicator of position confidence) (has 2 values – one for confidence the other for sensor quality/health)
18. Acceptance or Team Confidence Level

2.1.10 Sonograms and Sound Files

Sonograms, often referred to as grams, and sound files contain acoustic information that is being picked up by the receiver. They are very useful to the operators, giving them confidence in assessing contacts and classifying or identifying potential targets. Thus there must be some facility to select and send audio information. The grams can be sent as simple data records, such as beam-time series data with a client at the receiving end to transform the data into viewable grams or to be played as an audio file. The advantage in sending raw data is no distortion or loss of information occurs, which could occur if for instance the sound is converted to an MP3 or WAV audio file.

The specific format for the data will need to be determined for the NUW TDP however it may be advantageous to have a utility that converts audio data to MP3 or WAV

format for attachment to Email messages. The general information content of a sonogram or sound file is as follows:

1. Receiver ID (can then relate to Receiver Info for location, ownership, etc.)
2. Data type contained (Raw hydrophone data or beamformed)
3. Time of measurement
4. Bearing (if applicable)
5. Processing done (filtering applied or other processing)
6. Resolution of the data
7. Duration of sound file
8. Frequency reference points for interpreting data (e.g. Frequency of first and last points)
9. Data Format (array of values, MP3, WAV, etc.)
10. Acoustic Data (short snapshots only due to bandwidth constraints)

2.1.11 Email and Chat Messages

Email and chat messaging allow the sonar operators and tactical officers to communicate directly in an informal forum for problem solving and collaboration.† The ability for the task group to solve problems requires that the exchange of ideas facilitate combining information as a single unit. This will likely be most used while searching for and identifying targets. Email and chat will have lower priority than most other data due to bandwidth constraints and to ensure that required data and tactical commands get through in a timely fashion. It is most likely that Email and chat will be severely restricted as the tempo of an operation increases and may even be shut down during the prosecution phase.

2.1.12 Tactical Information

Tactical information is reserved as a high priority message for issuing commands and the exchange of tactical concepts. This is separate from Email and Chat, first because it maintains a high priority at all times and secondly it is reserved for the A/SWC, TACNAV or command level. This assures that the tactical information will be sent to other platforms and maintains the authority of command. Tactical Information consists of the following:

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† This is one area that allows the operators to exchange information and comments in a free-form style. The fleet uses SAMETIME (private communication with Paul Therrien). This runs in windows and Solaris environments. SAMETIME is an IBM Lotus product with very extensive capabilities to exchange different file formats and chat. It requires an underlying Domino server. The initial costs are high but this option should be investigated before deciding on a final implementation for chat.
A meeting was held with Paul Therrian of the Maritime Warfare Centre. It was pointed out that distraction issues are prevalent with chat since the users are busy on chat rather than on the task at hand. In addition, during high tempo operations all chat is shut down. Within the forces chat has been used extensively at the planning level with great success. Paul expressed that chat is highly successful in the forces when someone is solving a problem such as resolving equipment issues or communication problems, hence, chat is here to stay in the forces.

1. Time
2. Originating platform/personnel
3. Command message is a text string which may contain some of the following:
    a. Proposed sources/drop areas or positions
    b. Ping location requests
    c. Sonobuoy coverage area/pattern
    d. Allowed RF channels
    e. Proposed ping schedule and rate
    f. allocated ping time window
    g. Stop Pinging Now!

2.2 Operational Phase Considerations

If communication bandwidth is infinite then all data can be shared with all friendly platforms almost instantaneously. However, infinite bandwidth is never available to all platforms. This is true for IP radio communications such as being implemented in NUW where the communication rate is approximately 64 kilo-bits/second. One must ensure that enough information is shared to enhance performance and that the communication system and operator do not become so overloaded that the information use grinds to a halt. Thus, intelligent choices must be made when selecting data for transmission. The selection depends on the phase of the operation and the types and quantities of data available. The data requirements in the previous section describe the desired data types. In this section the use of the data and its priority will be discussed in the context of the operational phases of a platform performing ASW.

For the purposes of NUW, an ASW operation is broken into four phases:

1. Search and Detection,
2. Localization and Classification,
3. Prosecution, and
4. Post Prosecution.

During Search and Detection, the platforms are acquiring and analyzing all available data to find possible targets or contacts. Once a contact has been declared the operation moves into the Localization and Classification phase. In this stage, target tracking and improved analysis are used to better locate the target and to determine if it is a target of interest, what it is, and whether it is hostile. The operation may move back and forth between Search and Detection and Localization and Classification before finding a threat. The decision to engage a target moves the operation into the Prosecution phase. This is a period of intense activity with a high priority on exchanging information related to the target of interest that assures the task group knows where the target is and what it is doing. Once the engagement is complete the operation enters the Post Prosecution phase. In the Post Prosecution phase the task group tries to determine the effect of engagement on the target and returns to the Search and Detection phase.

The priority and urgency of the data during each of the phases is summarized in Table 1. The data priority is categorized into three levels:

1. **Must Have**, which provides essential information.
2. **Good To Have**, which will aid the warfighter but if missing will not jeopardize the team.
3. **Nice To Have**, which has value but is not essential.

As the operation proceeds through the phases to Prosecution, the urgency or timeliness increases for tactical data transmission between cooperating platforms. Accompanying the increased tempo is a shift in data priority. For instance, feature and contact data become less important as the operation moves from Search and Detection to Prosecution. This drop in importance is in direct correspondence with an increasing confidence in the target's track data. It should be noted that Table 1 refers to the operational phase against a target. Typically, the Search and Detection Phase never ceases even during the prosecution phase. Search and Detection may drop in priority as a platform moves to engage a target however the necessity to share data is reflected in the urgency to share information for Prosecution being greater than for Search and Detection.

Table 1: Data Value with ASW Operation Phase†

	MUST HAVE	GOOD TO HAVE	NICE TO HAVE
SEARCH AND DETECTION (I)	Environmental Data Receiver Information Source Information Ping Information Contact Data Tactical Information	Other Tracks Email/Chat Main Blast Data Feature Data Sonograms	Track Data
LOCALIZATION AND CLASSIFICATION (II)	Environmental Data Receiver Information Source Information Ping Information Contact Data Track Data Tactical Information	Other Tracks Email/Chat Main Blast Data Feature Data Sonograms	
PROSECUTION (III)	Receiver Information Source Information Ping Information Track Data Tactical Information	Other Tracks Contact Data	Email/Chat Main Blast Data Feature Data Environmental Data Sonograms
POST PROSECUTION	This has elements of both Search and Detection and Localization and Classification		

Increasing Urgency

Decreasing Priority

†. The order of information types within a box is also with increasing urgency downward.

Table 1 shows data exchange considerations for sending information to the primary platform forming the COP or between platforms of equal analytic capability. When unequal capabilities exist, the data priority will be different for the various platforms (see example in appendix C). For instance, the analytic capability to interpret grams may be centrally located. In this case, getting gram information to the analyst will have higher priority than for the analyst to transmit grams to the other platforms. The same is true for equal capabilities but mismatched sensors; receiving grams in frequency bands outside the platform's display capability is useless.

At the onset of the operation no tracks exist so they are nice to have. However as say other vessels are located and classified the operation will move back and forth between Search and Detection and Localization and Classification as each vessel is identified. This builds up a list of other tracks that will be shared between platforms during all phases of the operation in order to reduce the confusion and rediscovery of tracks that have already been identified.

In producing Table 1 the urgency is based on operation tempo and the priority on the value of the information in that phase. Combining both urgency and priority would tend to indicate that the over-all priority increases from the upper right towards the lower left of the table.

Table 1 was prepared as a thought exercise. Trials and simulations may alter the priority and urgency of each information type. For instance, in the above table email is assumed to be important but if it is missing it will not jeopardize the team. However, if email capability proves to lead to much faster decisions that lead to faster successful prosecutions then its priority may be recast as a Must Have item with higher priority.

2.3 Information Exchange Modes

Data sharing between platforms is straightforward from the point of view of placing information in the data server. However, considering the importance of the data and the frequency and quantity of information updates different exchange methods may be employed. What is important is to exchange the right information so the warfighter can act quickly and enhance the task group's effectiveness.

For this, a connection must be made to the data servers on other platforms. The connection must allow for selected desired information to be sent automatically or by request and for critical information to be broadcast and understood without prior knowledge of the information existence on the receiving platforms.

In order to discuss the information exchange methods further the definitions in the following table will be used:

Table 2: Exchange Methods Definitions

Subscription	A subscription is an agreement to receive or be given access to information.
Subscriber	A subscriber is the platform, operator, or system which is authorized to receive or access information.
Request or Pull	The request or pull method is used by the subscriber to request available information from the data source, i.e. information is sent only when asked for.
Notify	The notify method refers to information being sent out to other platforms to indicate that information is available. This usually occurs for subscribed data that one is interested in but wants control on the download. For example, interested platforms may want to obtain updated environmental predictions when available and have time to view the outputs.
Broadcast	The broadcast method refers to information being sent out to other platforms regardless of subscription status. For example, information about a newly discovered target is sent to all platforms to ensure that all team members are aware of the new threat.
Smart Push	The smart push method refers to a subscription that automatically sends updated information to the subscribing platform. This data is pushed to the receiving platform as long as the subscription is valid.
Smart Pull	The smart pull method is a pull of information generated by an automated request, for example, the receiving platform may want to generate a request for detailed waveform information without operator intervention when a ping notification is received for a ping type not contained in the platform's database.
Possibly	Possibly is a modifying keyword used to imply that an exchange will occur only if communication bandwidth is available.

Consider a platform joining a group. The first task is to establish a communication channel for information sharing. The next is to discover what information is available† and then to subscribe to the desired information. The data is chosen based on communication bandwidth constraints and the prioritization scheme and urgency discussed in the previous section. It may be possible for the user to tailor their requirements and exchange method to their needs. However, the amount and type of data available is too

† In some cases the discovery process may be expedited by having advance knowledge of the data available before the communication channel is opened.

large to configure individually each time. Instead, a default exchange method is applied to each data. The NUW information items and their default exchange methods are considered below for each phase of an ASW operation.

2.3.1 Search and Detection Phase (I)

In the Search and Detection phase all information that can lead to detections of targets is important. The information sharing modes needed to enhance target detection is summarized in Table 3.

In this phase, knowledge of acoustic conditions is needed to obtain good sonar performance predictions. Notifications of newly acquired environmental data are sent to ensure that it is immediately available to interested parties. The acoustic information itself is obtained via requests or possibly smart pulls so that operators can choose whether to incorporate the new data into the acoustic predictions they are running. Configuration files are to be sent via email so that the receiving platform can maintain control of its processing resources by choosing whether to incorporate the configuration into a prediction run or view it for comparison.

Receiver and Source information are needed to process sonar data. The first transmission will be a request of the settings and characteristics. Thereafter, only the changes are needed and are automatically updated using a smart push such as location, drift status, scope or orientation.

Main Blast data is primarily used on the platform that detects the main blast. The data is used to locate features in multistatic sonar. Thus, its effect on the information is incorporated into the feature data to locate the returns. Therefore, the value in exchanging Main Blast data may be as environmental information to tune sonar parameters. Sonar tuning need not be done often hence the exchange is by request or smart pull of the data.

Ping Information is crucial to proper acoustic processing. It is required in a timely fashion to ensure systems are configured properly to process the incoming sonar signals. Ping information sharing will occur often enough in an ASW operation that the operator would be overwhelmed if each transmission needed to be acknowledged or initiated. Hence, ping information should be shared automatically and the operator need only be notified if a ping has failed. In the event that a waveform is referenced that is not known on the receiving platform then an automated request (smart pull) for the waveform characteristics is sent to obtain the information. Previously unknown waveforms are placed into the platform's database for future reference.

Feature data has a great potential for fusion across platforms to detect new targets not easily found by a single sensor. The volume of feature data may be quite vast since it is a low level of data. Hence it may not be practical to share it in a low bandwidth network or a reduced amount could be shared, such as over a certain area or frequency band. If feature data is shared then it could be exchanged using a smart push or smart pull or by

Table 3: Search and Detection Phase (I)

INFORMATION		SHARE MODE	NOTES
Environmental Data	Sensor Data	Notify	Newly acquired Data
		Request	Information not in Database
	Modelling Information	Notify	Acoustic prediction outputs
		Request	Acoustic Predicition Run Data
		Notify via email	Configuration Files
		Request	Configuration file desired
Receiver Information	Common	Request	Characteristics and Settings
		Smart Push	Changes (e.g. Location, status)
	Towed Array	Request	at start
		Smart Push	needed for scope changes only (few values so exchange rather than notify)
	Sonobuoy	Request	Characteristics at start
		Smart Push	needed for changes, drift status, RF Channel Mode, Remaining Life (few values so exchange rather than notify)
Source Information		Request	Characteristics and Settings at start
		Smart Push	Changes (e.g. Location,depth etc.)
Main Blast Data		Smart Pull or Request	For Environmental Information
Ping Information	Waveform/Wavetrain Data	Smart Pull	Characteristics of new waveforms
		Smart Pull	Waveforms not in Database
	Next Ping Information	Smart Push	next transmission waveform and time
	Ping Status	Notify	success/failure
Feature Data	Common Passive Active	Possibly Request or Smart Pull or Smart Push	
Contact Data		Broadcast	When new contact is formed
Track Data			Do not yet exist
Sonograms		Request	
Email/Chat		Possibly Notifiy	
Tactical Information		Broadcast	

generating a a request for what exists in a certain region for comparison and fusion purposes.

Contact Data is crucial to the safety and operation of the task force. Thus, all platforms receive a broadcast of new contacts as they are formed.

In the search and detection phase Track data is not yet mature so sharing is not an issue.

Sonograms can be very useful to a skilled operator. However, they may be of little use in cases where there is no interpretation knowledge on the platform or if the frequency band does not match the sensors associated with the receiving platform. Therefore, sonograms are available by request only.

Email and chat are used for discussions between platforms and will only be supported if bandwidth is available. Due to the nature of email the preferred sharing method is by notification (i.e. the receiving platform is notified when an email is received and then is downloaded using a smart pull).† However, given excess network capacity emails could be automatically downloaded when bandwidth is available (smart pull based on free network capacity).

Tactical information is similar to email however it is critical that it be shared in a timely fashion and that these messages are received by all platforms. Therefore, tactical information is broadcast at high priority.

Echo Repeater information has not been included since it is of limited use in a tactical situation. For an example of echo repeater use see the example in appendix C.

2.3.2 Localization and Classification Phase (II)

During the Localization and Classification phase information sharing is focussed on determining what the contact is and where exactly it is. The sharing mode for each type of data is summarized in Table 4.

In this case, Environmental data is still important so notifications of new data continue to be sent, as in the first phase, and specific data is still obtained using smart pulls.

Receiver and Source information are still automatically exchanged using smart pushes. Note that only updates to the information are shared. In this stage a database of waveforms will have been created from previous pings so that in most cases only a waveform identification number is required.

Main Blast data use is unchanged from the Search and Detection phase.

† Some email services work in this manner. for instance, internet mail services such as Hotmail provide a list of email headings, the user then chooses which to download or view.

Table 4: Localization and Classification Phase (II)

INFORMATION		SHARE MODE	NOTES
Environmental Data	Sensor Data	Notify	Newly acquired Data
		Request	Information not in Database
	Modelling Information	Notify	Acoustic prediction outputs
		Request	Acoustic Predicition Run Data
		Notify via email	Configuration Files
		Request	Configuration file desired
Receiver Information	Common	Smart Push	Changes (e.g. Location, status)
	Towed Array	Smart Push	needed for scope changes only (few values so exchange rather than notify)
	Sonobuoy	Smart Push	needed for changes: drift status, RF Channel Mode, Remaining Life (few values so exchange rather than notify)
Source Information		Smart Push	Changes (e.g. Location,depth etc.)
Main Blast Data		Smart Pull or Request	For environmental adaptation
Ping Information	Waveform/Wavetrain Data	Smart Push	Characteristics of new waveforms
		Smart Pull	Waveforms not in Database
	Next Ping Information	Smart Push	next transmission waveform and time
	Ping Status	Notify	success/failure
Feature Data	Common Passive Active	Possibly Request or Smart Pull or Smart Push	
Contact Data		Broadcast	When new contact is formed or status change of existing contact
		Smart Push	Changes in Contact position
Track Data		Broadcast	New tracks formed
		Smart Push	Tracks of interest
Sonograms		Request	
Email/Chat		Possibly Notify	
Tactical Information		Broadcast	

Ping information is still critical with new waveform information being obtained via smart pulls, next ping information being sent to interested parties using a smart push and ping status as a notification.

Feature data may be useful in tracking algorithms however its importance is still unchanged. As such it may be shared in limited areas or filtered for specific attributes before sharing.

Contact data is extremely important in this phase. Any change in contact status is broadcast to all participating platforms and contact information is exchanged using a smart push so that the most up to date information is available.

Track data now exists and can be shared. Broadcasts of newly created tracks are sent to other platforms. Tracks of interest are smart pushed. The target track is likely to always be shared while other vessels that may affect the operation may be optionally shared.

Sonograms, Email and Chat and Tactical information sharing remain unchanged. More email discussions relating to the particular target of interest is expected.

2.3.3 Prosecution Phase (III)

In the prosecution phase the operational tempo will be high and most communication resources will be focussed on pursuing the target. Limits on what to send will be imposed to accommodate more critical information related to the target.

Although environmental data can still be shared it will only be transmitted if there are changes that affect the operation. Bear in mind that the environmental data required to locate the target has already been obtained in the first two operational phases so the need for sharing diminishes.

Receiver, Source and Ping information are still important in tracking the target. Hence it is still shared as before using only the changed information.

Main Blast data, like Environmental data, is only needed if it affects the operation. As such, Main Blast data is still available by request but its priority is reduced.

Feature information is automatically exchanged only if it is required for data fusion algorithms used to track the target. In order to maintain bandwidth only a very small set of feature information is shared via smart push if required.

Contact data is still shared and is of high importance especially when the status of the contact changes (like the target changing from hostile or a new hostile target is located).

Tracks are still shared same as in the previous phase; however, information on the target of interest will be given a higher priority than other tracks and is obtained via smart pushes while other tracks could be retrieved using a smart pull.

Table 5: Prosecution Phase (III)

INFORMATION		SHARE MODE	NOTES
Environmental Data	Sensor Data Modelling Information	Notify	Only if changed from Phase I/II
		Request	Information only if changed and needed
Receiver Information	Common	Smart Push	Changes (e.g. Location, status)
	Towed Array	Smart Push	needed for scope changes only (few values so exchange rather than notify)
	Sonobuoy	Smart Push	Needed for changes, drift status, RF Channel Mode, Remaining Life (few values so exchange rather than notify)
Source Information		Smart Push	Changes (e.g. Location,depth etc.)
Main Blast Data		Smart Pull or Request	For environmental adaptation
Ping Information	Waveform/Wavetrain Data	Smart Push	Characteristics of new waveforms
		Smart Pull	Waveforms not in Database
	Next Ping Information	Smart Push	next transmission waveform and time
	Ping Status	Notify	success/failure
Feature Data	Common Passive Active	Smart Push	Only if needed for fusion to maintain tracking on contact
Contact Data		Broadcast	When status change of existing contact
		Smart Push	Changes in Contact position
Track Data		Broadcast	New tracks formed
		Smart Push	Tracks of interest
		Smart Push or Smart Pull	Other tracks
Sonograms		Request	Only if changed from Phase I/II
Email/Chat			Probably shut down
Tactical Information		Broadcast	

Sonograms may be requested but as for environmental data the signatures of interest will have been determined in the previous phases so the importance of sharing is very low unless it affects the operation outcome (such as a frequency shift of the target).

Due to the high tempo of this phase operators may not have time to deal with email and since email potentially can occupy a lot of bandwidth it will probably be shut down if not given a very low priority.

Tactical Information remains at the highest priority and is shared through broadcasts to all participating platforms.

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3. Global Exchange Requirements

The previous section outlines specific information types and their exchange requirements. There are more issues to sharing information than just defining the required components and agreeing on a syntax. There are issues such as information ownership, and information synchronization. These issues and others are raised below without offering specific solutions. The intent here is to present these issues for discussion and to ensure that their significance in information sharing is not overlooked in later work.

3.1 Information Ownership

Ownership can indicate who owns or controls an asset. For NUW, the tangible assets a platform controls are sources, sensors and echo repeaters. Thus the ownership of the associated information is obviously with the platform controlling it.

Tangible assets form only a small amount of the information needed to form the COP. Hence, ownership of *all* information must be dealt with. Designation of an owner gives responsibility for producing the information and control over acceptance of updates. This allows for a controlled approach to forming an accepted set of data. Thus, in a team environment the owner becomes a mediator to ensure that the most reasonable or accepted information updates are promulgated. In contrast, if no owner is designated and all team members can update the information then the data set may become unstable as it jumps from one platform's view to another's as the data is overwritten by the different views.

For some data, the ownership is inferred by association - such as for ping characteristics or ping success being with the source owner. Or the basic feature data being owned by the platform with the sensor and initial processing. The ownership of other information created by team efforts is not as clear. For example if a track is formed by information from multiple platforms who is the designated owner? One solution is to designate the platform/user that first declared the track. However, what if the platform leaves the operation or the target moves out of its sensor range into another platform's sensor area. In these cases, a mechanism for passing ownership from one platform to another must be introduced. This implies that the owner must be expressed in the information structures used and that when ownership is passed from one platform to another, systems must automatically adjust to obtaining the information from possibly a different data server than it had prior to the ownership change.

3.2 Synchronization

One of the challenges in data sharing among teams in different locations is keeping the basic information synchronized between processing centers. For networked warfare applications the requirement is to keep the useful information up to date on each of the participating platforms. If one platform falls behind in updates then the tracks it creates or conclusions drawn will not only be out of date with the rest of the team but may

unknowingly lead to the collective acceptance of an erroneous tactical picture. Thus as connections are lost and reestablish the systems must rapidly update all pertinent information.

In order to enhance the synchronization it may be necessary to provide information on what data has been changed in a specified time interval. For instance, to ensure synchronization a check of all items sent in the last half hour may be made. Based on the results only the histories of what has been changed will be updated. To ensure that the most important information is updated first, the receiving platform may ask for data in a specified order. The order may be specified in type and in time direction of update (earliest to latest or vice-versa).

On a more immediate time scale, information blocks may be tagged sequentially so that missing blocks are immediately identified. For example, pings are uniquely identified by an event ID. The event ID could be used to identify missed ping information packets if the events are numbered sequentially.

3.3 Common Operating Picture

In the case of updating a common understanding of the tactical picture a distinction must be made between the accepted information and the working information. For example there is a difference between the track and feature associations an operator is considering on his terminal versus the accepted course and target information by the team of platforms. There needs to be a separation between the operator's display and the common operating picture.

This can be accomplished by providing "scratch" screens for the users to work on and try possible solutions and another view with the accepted picture. The accepted picture would need to have extra information reflecting the degree of acceptance and quality of the information as well as the owner of each information item. A *team scratch* screen would provide a collaborative work area for other platform users to compare ideas and results and a *user scratch* screen would allow the single user to work locally. Allowances must be made and collaboration tools implemented for information to flow from the user scratch screen to the team scratch screen and finally to the accepted picture screen.

3.4 Collaboration Tools

It is imperative that a team of platforms has tools to facilitate collaboration. Much can be accomplished with Email and chat however finding the context for display and the labour of creating Emails can be tedious. There needs to be mechanisms to relay values across systems and displays through simple means. These transmissions could be quickly prepared by operators simply clicking on a data item in their display and choosing a send command from a drop down menu. The transmitted information would contain the pertinent information including display context information[†]. On the receiving end, the collaboration information must be automatically decoded with its context so

that it can either be placed directly on the operator's displays or a notification of what information is contained can be given to the operator for a decision on what to do with it, such as accept, ignore, or store for future use.

An additional consideration is directing the transmission of information while collaborating. Email obviously has the capability for team wide and individual distribution and similar capabilities should be implemented in any collaboration tooling. This capability is also related to the capability to send information between scratch screens and the COP, as indicated in section 3.3, and could be included as a selection on where to send information.

3.5 Time Synchronization and Accuracy

In order to process the information properly the time stamps on the data must be synchronized to a common reference. The Global Positioning System (GPS) is the most likely source capable of synchronizing all platforms in the task group and will be used in NUW. If GPS is not available then some other method must be employed.

Some of the sonar signal processing requires accuracies down to 10's of milliseconds hence a common time representation down to 1 millisecond resolution in all reports will ensure enough accuracy for present processing needs and should address most needs into the future.

3.6 Automation

One of the issues which must be considered is operator overload. With so much organic information available and a steady flow of inorganic data, the operator could be hard pressed to keep up with the influx. Automated methods for accepting off-board data and introducing it into processing streams must be considered to reduce this stress. In addition, interfaces to control the acceptance criterion must also be implemented (for example automatic acceptance - versus acceptance with notification and ignore states). This will be the subject of future research.

3.7 Information from Other Sources

Given an operation or trial in which information is exchanged, there will potentially be participants which are not capable of exchanging the types of information presented over an IP network. These partners may be able to provide and receive information over

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[†]For example, some of the transmission functionality exists in OTH Gold messages such as add and drop contacts, delete tracks, and area definitions, etc. OTH Gold also includes messages for sending image reference points for overlaying images like on the chart. However, OTH Gold is not as rich in its information types as is desired for the work here. A better choice is xml data structures which can be tailored to the needs.

other communications protocols like Link 11 or OTH Gold. It is desirable to be able to make use of the information as much as possible. Hence, methods of mapping the information into other communications streams must be considered. A preliminary look at what data exists in some of the communications protocols in use and data stores is given in appendix B. From the comparative list in appendix B it is evident that the common existing communications protocols do not have the richness of the information proposed here. In some cases they were not originally designed for maritime operations or have been addressed mostly the command and control level, ignoring both collaboration and amalgamation of sensor information that is sought in NUW.

4. Conclusions and Future Plans

As stated, The NUW TDP will demonstrate that information sharing improves the accuracy of the COP as well as increase the speed with which the COP is formed. The information types required for sharing between platforms working to form the COP has been presented. Twelve types of information were identified:

1. Environmental Data
2. Receiver Information
3. Source Information
4. Echo Repeater Information
5. Ping Information
6. Feature Data
7. Main Blast Data
8. Contact Data
9. Track Data
10. Sonograms
11. Email and Chat Messages
12. Tactical Information

The details of each information type goes beyond the present command and control data available in existing communications protocols like Link 11 and OTH Gold. The detail reaches down to the sensor level.

An added complexity is the limited available bandwidth for sending the information. It was identified that rather than transmitting everything, careful choices must be made and priorities and urgency must be considered. To this end an analysis of data use was considered during an ASW operation. The relative importance of the data will change with the phase of the operation and the communicated information choices must reflect these changing priorities. Exchange modes for the different phases were also considered. Some information is automatically shared while others only on request. This will both prevent operator overload and help manage the changing priorities for the information.

Some aspects of data sharing and collaboration were also identified and discussed. Information ownership, automation, information synchronization, and the availability of information from other sources must also be considered.

What has been laid out here is a framework of requirements for moving forward and implementation into information exchange experiments. These experiments will refine many of the concepts presented here. The refinements are expected to be mostly in resetting priorities with a few adjustments to the underlying information elements. These will be reported as the NUW TDP proceeds.

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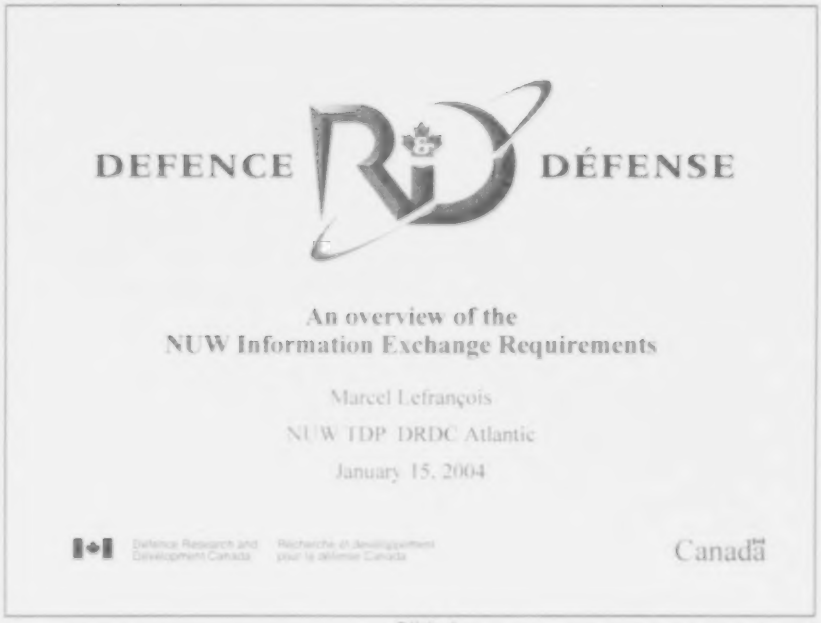
Appendix A - NUW TDP Data Exchange List

The following overhead slides contain information exchange requirements that resulted from a series of meetings with sonar experts. During these discussions 10 information types were identified and summarized in the following slides. The slides are provided here for reference. The data types have subsequently been extended to account for ownership issues and other needs that were identified in the preparation of this document. The list below is also incomplete in that two information types are missing: Main Blast data and Echo Repeater information. It was also recognized during the preparation of this document that the share modes needed to be expanded since the terms used here limited the number of sharing modes without added explanations.



Slide 1.

Overview

- Aims and Assumptions
- 10 Information Types
- List of Information Type Components
- Operational Phase Considerations
- Information Exchange Modes

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Slide 2.

Aims and Assumptions

- Share Information between platforms that aids the task group in UWW so they act as a team
- Building the COP using shared information
- STB – NUW connection using IP over UHF
- Assume the required information (in next few slides) is available or capability can be added.
- Not all information is required in a structure
- Send only changed values
- Aim of this presentation is to describe the required information – not the format.

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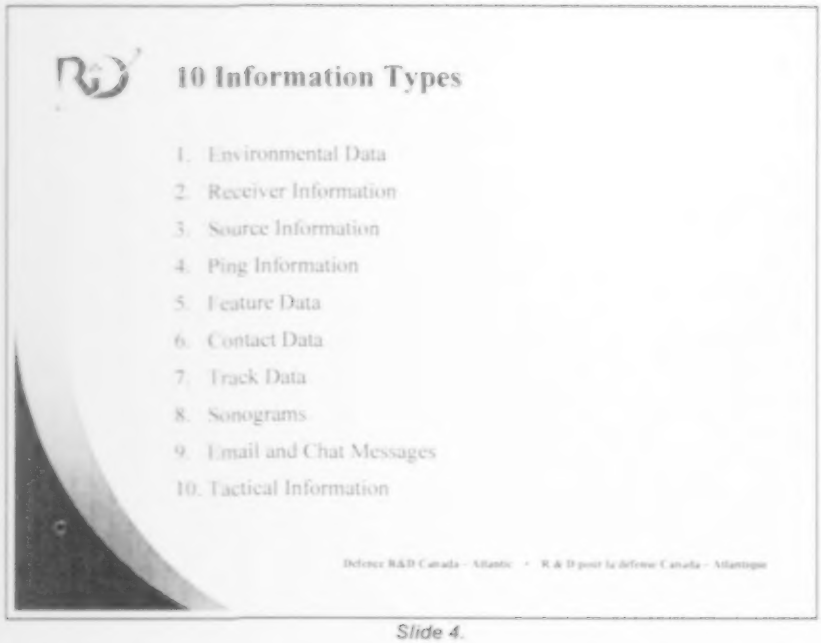
Slide 3.


10 Information Types
1. Environmental Data
2. Receiver Information
3. Source Information
4. Ping Information
5. Feature Data
6. Contact Data
7. Track Data
8. Sonograms
9. Email and Chat Messages
10. Tactical Information
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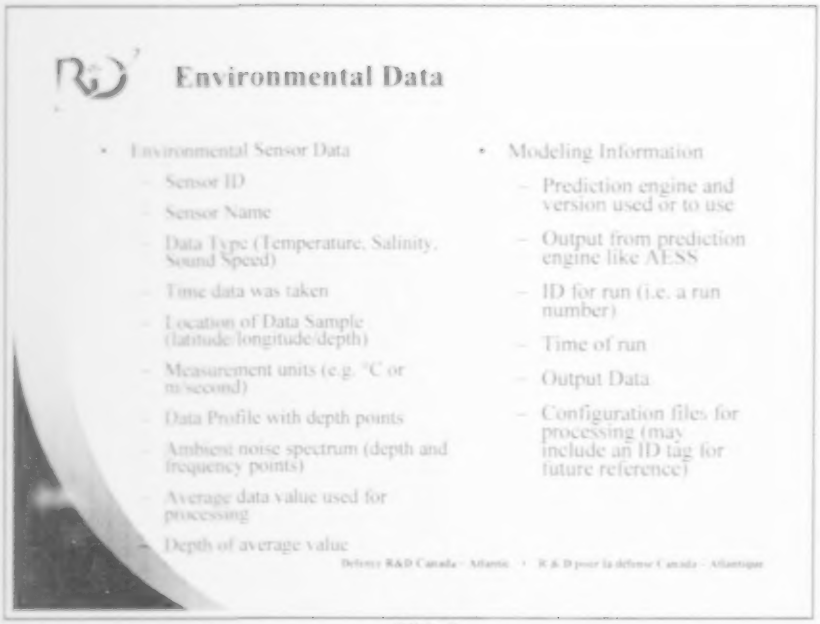
Slide 4.


Environmental Data
• Environmental Sensor Data
– Sensor ID
– Sensor Name
– Data Type (Temperature, Salinity, Sound Speed)
– Time data was taken
– Location of Data Sample (latitude/longitude/depth)
– Measurement units (e.g. °C or m/second)
– Data Profile with depth points
– Ambient noise spectrum (depth and frequency points)
– Average data value used for processing
– Depth of average value
• Modeling Information
– Prediction engine and version used or to use
– Output from prediction engine like AESS
– ID for run (i.e. a run number)
– Time of run
– Output Data
– Configuration files for processing (may include an ID tag for future reference)
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Slide 5.

Receiver Information (Common)

- Sensor ID
- Sensor Name
- Sensor Class (array or buoy)
- Sensor Type (specific array or buoy type)
- Time
- Operating Status
- Latitude and Longitude
- Sensor Depth
- Sensor Speed
- Sensor Heading (direction of motion)
- Sensor Heading (orientation of beams)
- Sensor Gain (AGC mode or gain setting)
- Sensor Sensitivity (Possibly array of gain versus frequency)

Slide 6.

Receiver Information (Specializations)

- Towed Array
  - Scope
  - Number of Beams
  - Beam Angles with respect to the forward direction of the array
- Sonobuoy
  - RF Channel
  - Remaining Life
  - Drift Status
  - Splash point with unknown, low or good accuracy or DMS plot stabilization info
  - Buoy Mode (if applicable)
  - RF channel mode (transmitting/not transmitting)
  - Method of position determination

Slide 7.

Source Information

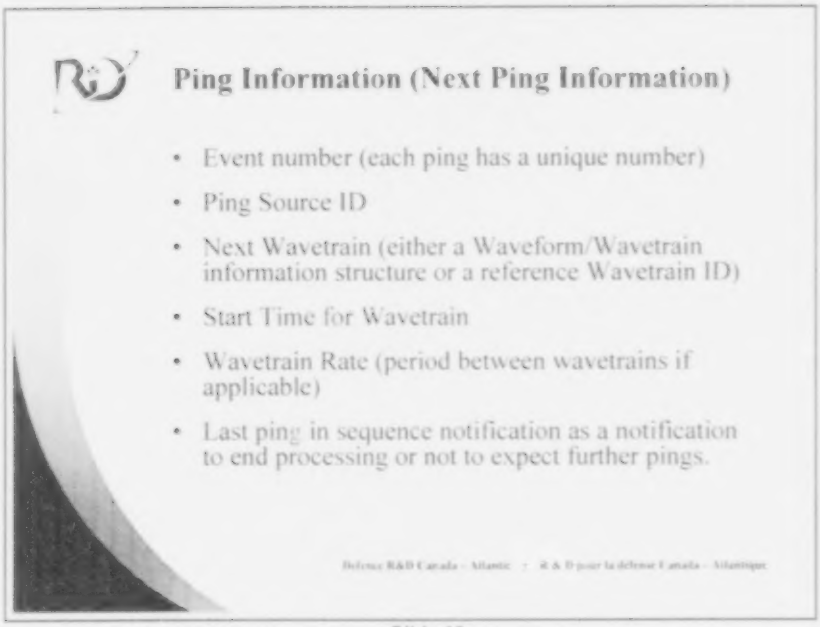
- Source ID
- Source Name
- Source Type
- Time
- Location (Latitude and Longitude)
- Source Depth
- Source Speed
- Source Heading
- Source Beam Heading and Vertical Steering Direction

Slide 8.

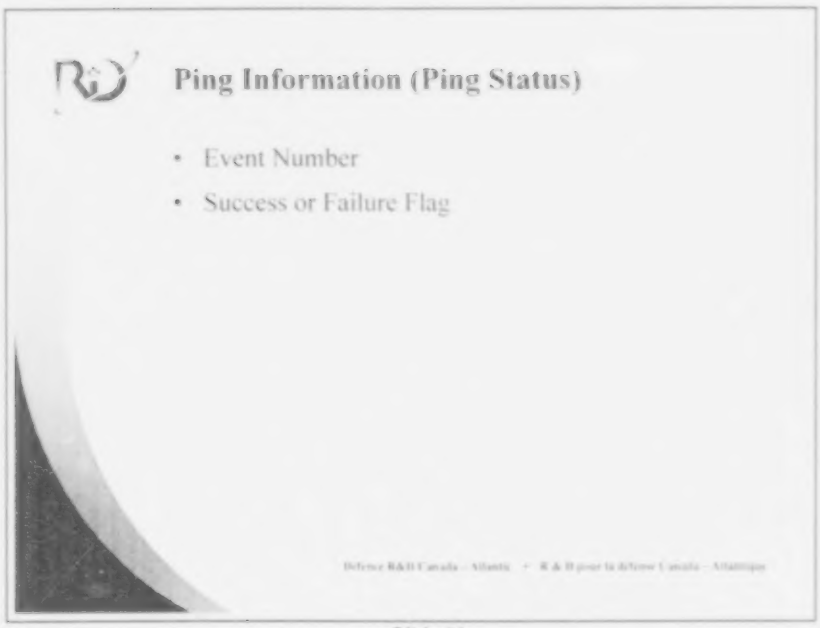
Ping Information (Wavetrains / Waveforms)

- Waveforms
  - Wavetrain ID
  - Wavetrain Name
  - Wavetrain Source ID
  - Wavetrain Start Time
  - Number of Waveforms Forming the Wavetrain
  - Waveform Descriptions
- Waveform Description
  - Waveform ID
  - Waveform type (e.g. CW, FM)
  - Envelope type (e.g. Hamming)
  - Duration of waveform
  - Offset Time from start of wavetrain
  - Amplitude or source level
  - Source level reference (absolute/relative)
  - Characteristic Frequency 1
  - Characteristic Frequency 2
  - Characteristic Frequency 3
  - Sampled Waveform (To handle other waveforms like Costas)

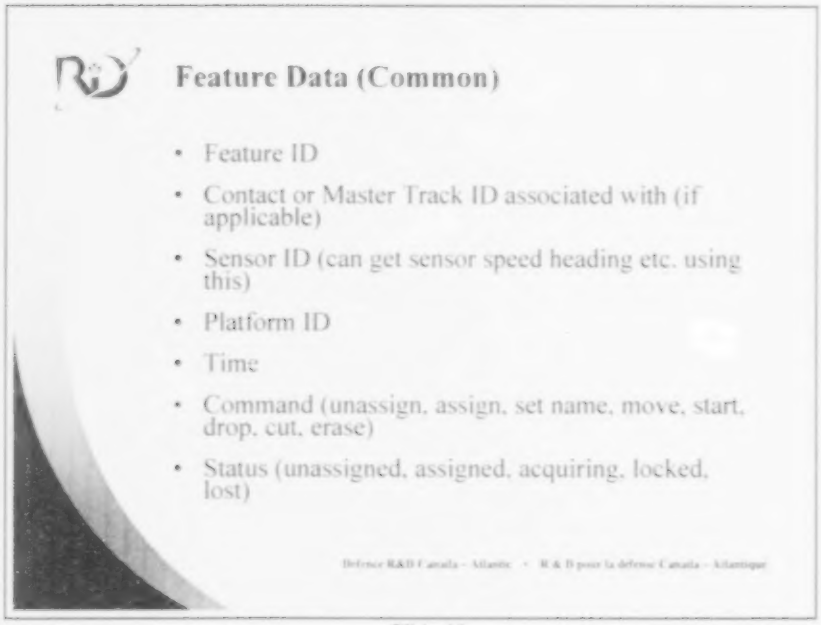
Slide 9.


Ping Information (Next Ping Information)
• Event number (each ping has a unique number)
• Ping Source ID
• Next Wavetrain (either a Waveform/Wavetrain information structure or a reference Wavetrain ID)
• Start Time for Wavetrain
• Wavetrain Rate (period between wavetrains if applicable)
• Last ping in sequence notification as a notification to end processing or not to expect further pings.

Slide 10.



Slide 11.


Feature Data (Common)
• Feature ID
• Contact or Master Track ID associated with (if applicable)
• Sensor ID (can get sensor speed heading etc. using this)
• Platform ID
• Time
• Command (unassign, assign, set name, move, start, drop, cut, erase)
• Status (unassigned, assigned, acquiring, locked, lost)
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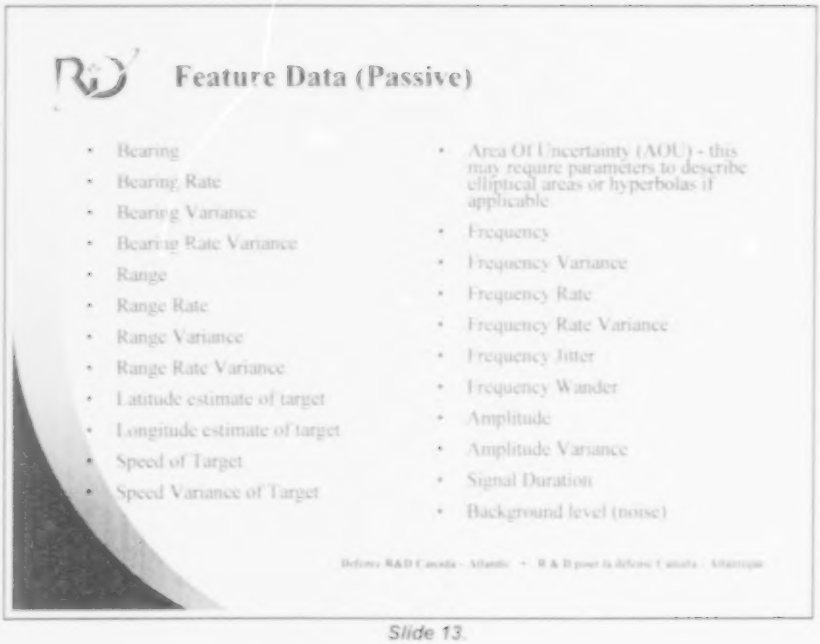
Slide 12.


Feature Data (Passive)
• Bearing
• Bearing Rate
• Bearing Variance
• Bearing Rate Variance
• Range
• Range Rate
• Range Variance
• Range Rate Variance
• Latitude estimate of target
• Longitude estimate of target
• Speed of Target
• Speed Variance of Target
• Area Of Uncertainty (AOU) - this may require parameters to describe elliptical areas or hyperbolas if applicable
• Frequency
• Frequency Variance
• Frequency Rate
• Frequency Rate Variance
• Frequency Jitter
• Frequency Wander
• Amplitude
• Amplitude Variance
• Signal Duration
• Background level (noise)
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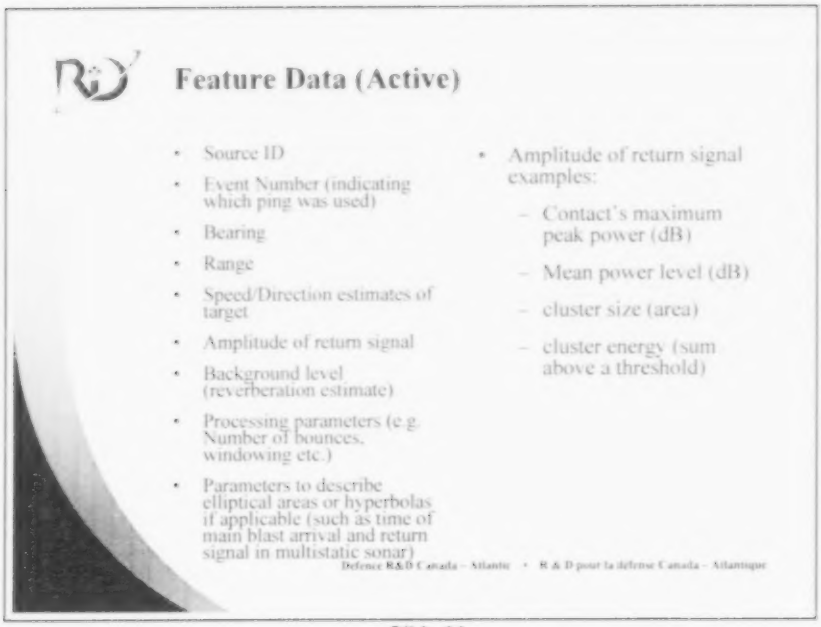
Slide 13.


Feature Data (Active)
• Source ID
• Event Number (indicating which ping was used)
• Bearing
• Range
• Speed/Direction estimates of target
• Amplitude of return signal
• Background level (reverberation estimate)
• Processing parameters (e.g. Number of bounces, windowing etc.)
• Parameters to describe elliptical areas or hyperbolas if applicable (such as time of main blast arrival and return signal in multistatic sonar)
• Amplitude of return signal examples:
– Contact's maximum peak power (dB)
– Mean power level (dB)
– cluster size (area)
– cluster energy (sum above a threshold)
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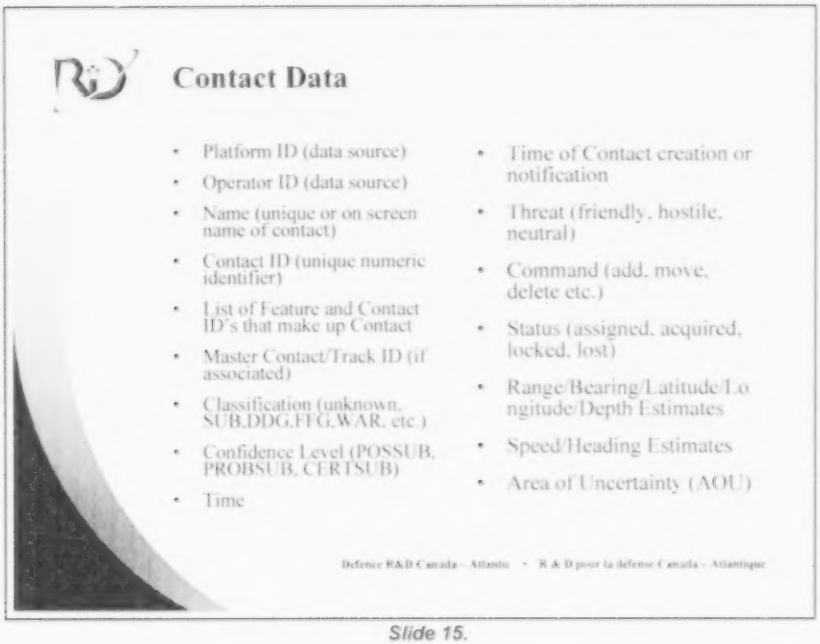
Slide 14.


Contact Data
• Platform ID (data source)
• Operator ID (data source)
• Name (unique or on screen name of contact)
• Contact ID (unique numeric identifier)
• List of Feature and Contact ID's that make up Contact
• Master Contact/Track ID (if associated)
• Classification (unknown, SUB,DDG,FFG,WAR, etc.)
• Confidence Level (POSSUB, PROBSUB, CERTSUB)
• Time
• Time of Contact creation or notification
• Threat (friendly, hostile, neutral)
• Command (add, move, delete etc.)
• Status (assigned, acquired, locked, lost)
• Range/Bearing/Latitude/Longitude/Depth Estimates
• Speed/Heading Estimates
• Area of Uncertainty (AOU)
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Slide 15.

Track Data

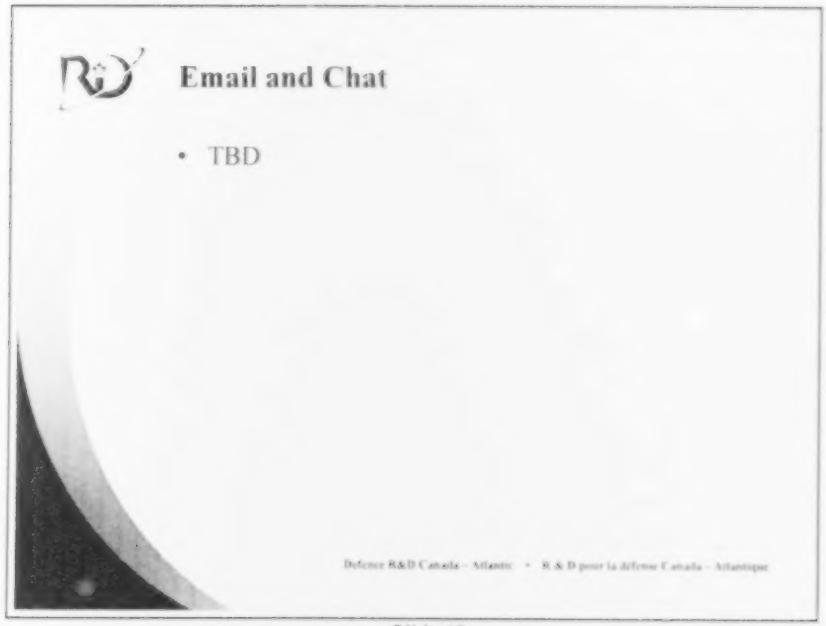
- Platform ID (data source)
- Operator ID (data source)
- Name (unique or on screen name of track)
- Track ID (unique numeric identifier
- List of Feature, Contacts and Tracks that make up Track
- Master Track ID (if associated)
- Classification (unknown, SUB, DDG, FFG, WAR, etc.)
- Battle Space (Surface/Subsurface)
- Mode (transiting, maneuvering, unknown)
- Time
- Time of Track Creation
- Threat (unknown, friendly, hostile)
- Command (unassign, assign, extrapolate, set speed etc., delete, move, localize)
- Status (unassign, assign, extrapolate, interpolate, localize)
- Longitude/Latitude/Depth/Latitude Error/Longitude Error/Depth Error
- Speed/Heading Estimates
- DQI Level (Data Quality Index – indicator of position confidence) (has 2 values – one for confidence the other for sensor quality/health)

Slide 16.

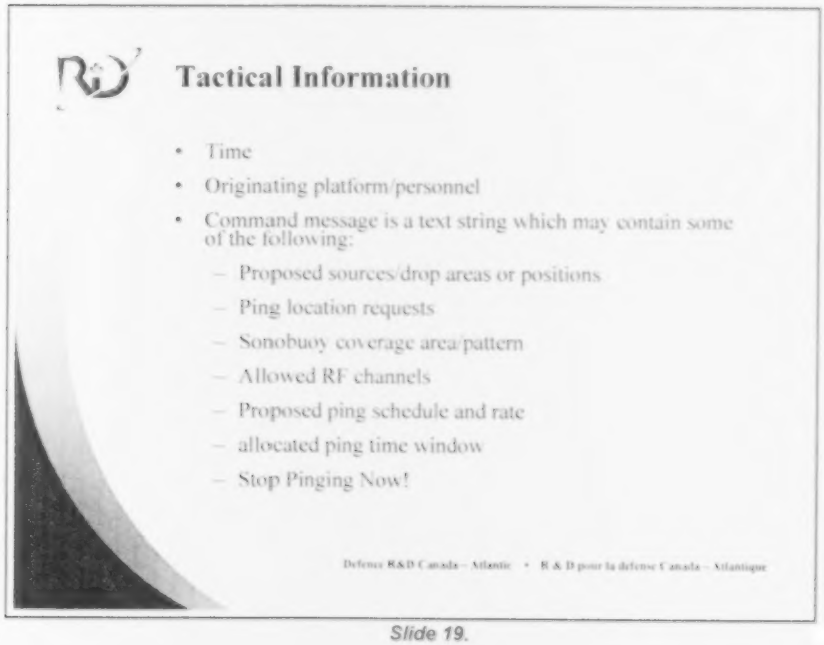
Sonograms

- Receiver ID (can then relate to Receiver Info for location etc.)
- Data type contained (Raw hydrophone data or beamformed)
- Time of measurement
- Bearing (if applicable)
- Processing done (filtering applied or other processing)
- Resolution of the data
- Duration of sound file
- Frequency reference points for interpreting data (e.g. Frequency of first and last points)
- Data Format (array of values, MP3, WAV, etc.)
- Acoustic Data (short snapshots only due to bandwidth constraints)

Slide 17.



Slide 18.


Tactical Information
• Time
• Originating platform/personnel
• Command message is a text string which may contain some of the following:
– Proposed sources/drop areas or positions
– Ping location requests
– Sonobuoy coverage area/pattern
– Allowed RF channels
– Proposed ping schedule and rate
– allocated ping time window
– Stop Pinging Now!
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Slide 19.

Information Priority

- **Priority based on Value:**
  - **Must Have**, which provides essential information.
  - **Good To Have**, which will aid the warfighter but if missing will not jeopardize the team.
  - **Nice To Have**, which has value but is not essential.
- **Information Urgency:**
  - Based on operation tempo

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Slide 20.

Data Value With Operational Phase (ASW)

	MUST HAVE	GOOD TO HAVE	NICE TO HAVE
SEARCH AND DETECTION (I)	Environmental Data Receiver Information Source Information Ping Information Contact Data Tactical Information	Email/Chat Feature Data Sonograms	Track Data
LOCALIZATION AND CLASSIFICATION (II)	Environmental Data Receiver Information Source Information Ping Information Contact Data Track Data Tactical Information	Email/Chat Feature Data Sonograms	
PROSECUTION (III)	[illegible]	Contact Data	Email/Chat Feature Data Environmental Data Sonograms
POST PROSECUTION	This has elements of both Search and Detection and Localization and Classification		

Increasing Urgency

Decreasing Priority

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Slide 21.

Information Priority

- **Priority based on Value:**
  - **Must Have**, which provides essential information.
  - **Good To Have**, which will aid the warfighter but if missing will not jeopardize the team.
  - **Nice To Have**, which has value but is not essential.
- **Information Urgency:**
  - Based on operation tempo

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Data Value With Operational Phase (ASW)

	MUST HAVE	GOOD TO HAVE	NICE TO HAVE
SEARCH AND DETECTION (I)	Environmental Data Receiver Information Source Information Ping Information Contact Data Tactical Information	Email/Chat Feature Data Sonograms	Track Data
LOCALIZATION AND CLASSIFICATION (II)	Environmental Data Receiver Information Source Information Ping Information Contact Data Track Data Tactical Information	Email/Chat Feature Data Sonograms	
PROSECUTION (III)	Receiver Information Source Information Ping Information Track Data Tactical Information	Contact Data	Email/Chat Feature Data Environmental Data Sonograms
POST PROSECUTION	This has elements of both Search and Detection and Localization and Classification		

Increasing Urgency

Decreasing Priority

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Asymmetric Partners

- Assume the following:
  - Command Platform
    - AESS engine,
    - pinger (pinger control),
    - Sonar analyst,
    - no sonar bands overlap
  - 2nd Platform
    - has sonar sensors and operators

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Data Values from Perspective of Command Platfrom Sharing Information with Others

	MUST HAVE	GOOD TO HAVE	NICE TO HAVE
SEARCH AND DETECTION (I)	Environmental Data Receiver Information Source Information Ping Information Contact Data Tactical Information	Email/Chat Feature Data	Sonograms Track Data
LOCALIZATION AND CLASSIFICATION (II)	Environmental Data Receiver Information Source Information Ping Information Contact Data Track Data Tactical Information	Email/Chat Feature Data	Sonograms
PROSECUTION (III)	Receiver Information Source Information Ping Information Track Data Tactical Information	Contact Data	Email/Chat Sonograms Feature Data Environmental Data
POST PROSECUTION	This has elements of both Search and Detection and Localization and Classification		

Increasing Urgency

Decreasing Priority

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Data Values from Perspective of other Platform Sharing Information

	MUST HAVE	GOOD TO HAVE	NICE TO HAVE
SEARCH AND DETECTION (I)	Environmental Data Receiver Information Contact Data Tactical Information	Email/Chat Feature Data Sonograms	Source Information Ping Information Track Data
LOCALIZATION AND CLASSIFICATION (II)	Environmental Data Receiver Information Contact Data Track Data Tactical Information	Email/Chat Feature Data Sonograms	Source Information Ping Information
PROSECUTION (III)	Receiver Information Data Tactical Information	Contact Data	Source Information Ping Information Email/Chat Feature Data Environmental Data Sonograms
POST PROSECUTION	This has elements of both Search and Detection and Localization and Classification		

Increasing Urgency

Decreasing Priority

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Information Share Modes

- **Subscription:** A subscription is an agreement to receive or be given access to information.
- **Subscriber:** A subscriber is the platform, operator, or system which is authorized to receive or access information.
- **Exchange:** Exchange method refers to a subscription that automatically sends updated information to the subscribing platform, i.e. data is pushed to the receiving platform as long as the subscription is valid.
- **Request:** The request method is used by the subscriber to pull available information from the data source, i.e. information is sent only when asked for.
- **Notify:** The notify method refers to information being sent out to other platforms. This can occur for subscribed data as well as for unsubscribed data (e.g. interested platforms are notified about new environmental data while a new contact will be broadcast to all plat-forms).
- **Possibly:** Possibly is a modifying keyword used to imply that an exchange will occur only if communication bandwidth is available.

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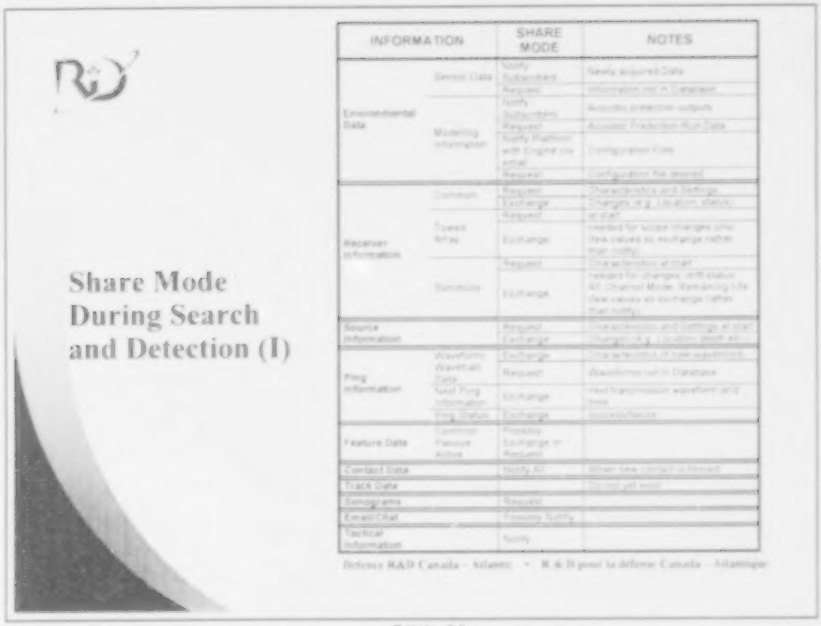
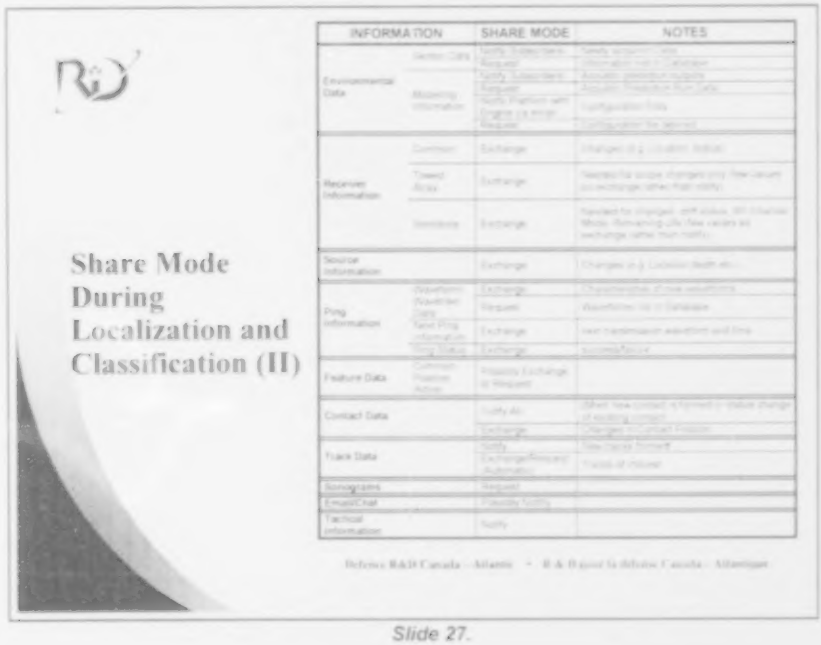


Slide 26.



Slide 27.

Asymmetric Partners

- Assume the following:
  - Command Platform
    - AESS engine,
    - pinger (pinger control),
    - Sonar analyst,
    - no sonar bands overlap
  - 2nd Platform
    - has sonar sensors and operators

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Considerations

- There will need to be clients and middleware between the platforms to mitigate the information transfer (thus the two systems are isolated to some degree except for this connection)
- Need to look at issues in discovery of available data and connection
- How do we handle latency? Such as a submarine coming in and out of transmission (or for that matter an MPA)
- Everything I have said is version 0.1 I would expect we will learn and need the suite modified as we go (Bitkeeper)

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Appendix B - Information from Other Sources

There is a recognized overlap between some of the required information presented here and what is available in existing message formats like Link 11 or OTH Gold. As such, during implementation and development of a naval information sharing system, existing information sources will be tapped. Further, it is highly likely that given a team of platforms that some will only be able to receive and send information using presently existing protocols. In order to participate in a networked operation like NUW, a mapping of the information types from one protocol to another is needed.

As an aid to future work, a comparison of the information availability from the other protocols is given below in table 6. The table below demonstrates three things:

1. some of the existing information types can be referenced to the required data types presented in this document,

2. that common existing formats are inadequate for obtaining sensor level data, and

3. both IMPACT and the STB must be modified to handle some of the information required.

It should be noted that although every effort has been made to accurately represent these mappings, the intricacies of the models make this an error prone exercise. For instance, it may be possible to obtain some of the information by using multiple messages or messages in a manner not identified at the time of the preparation of this document. Hence, the tables below should be used as a guide rather than a definitive reference.

The information types shown in the first column of table 6 are those presented and defined in Chapter 2. Other information services are compared to it in the subsequent columns. The data servers in NUW are the system data servers on the surface ship and in the Maritime Patrol Aircraft (MPA). The data servers are the System Test Bed (STB) on the surface ship and IMPACT on the MPA. Both systems are based on the US DoD COE 4.7 environment. Two communication protocols built into the COE and also available from many Naval vessels are Link 11 and OTH Gold. These are compared to the desired information list. Finally, a data model and translation layer that is under current development and investigation in this context is LC2IEDM, which is shown here with its mappings to the information requirement presented in this document.

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Environmental Data					[e]
Environmental Sensor Data					
Sensor ID				M	X
Sensor Name					X
Platform ID					X
Sensor Class					
Data Type				X	
Time data was taken					X
Latitude				X	X
Longitude				X	X
Depth				X	X
Measurement Units				X	
Depth of average value					?
Data Profile with depth points				X	
Ambient noise spectrum					
Average data value used for processing	X	X			
Model Outputs/Inputs					
Platform ID					X
Prediction engine and version used or to use					
Run ID					
Time of Run					

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Output Data					
Configuration files for processing					?[f]
Receiver Information					
Sensor ID			X		X
Sensor Name					X
Platform ID					X
Sensor Class			X		?
Sensor Type			X		?
Time	X	X			
Operation Status					
Latitude and Longitude	X	X			X[g]
Longitude	X	X			X[g]
Sensor Depth	X	X	X		X
Sensor Speed	X	X			X
Sensor Heading	X	X			X
Sensor Beam Heading	X	X			
Sensor Gain	X	X			
Sensor Sensitivity	X	X			
Calibration Status					
Receiver Information - Towed Array					
Scope	X	X			
Number of Beams					

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Beam angles with respect to front of array					
Left/Right Ambiguity Flag					
Receiver Information - Sonobuoy					
RF Channel		X	X		
Remaining Life		M	X		
Drift Status					[h]
splash point with unknown, low or good accuracy or DMS plot stabilization info					
Buoy Mode (if applicable)			M		
RF channel mode (transmitting/not transmitting)			M		
Method of position Determination					[i]
Source Information					
Source ID				X	X
Source Name					X
Platform ID					X
Ping Source Type					X[j]
Time	X				X
Latitude	X	X			X[g]
Longitude	X	X			X[g]
Source Depth	X			X	X
Source Speed	X	X			X
Source Heading	X	X			X

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Source Beam Heading					
Source Beam Vertical Steering Direction					
Source Level				X	
Source Level Units				X	
Calibration Status					
Echo Repeater Information					
Echo Repeater ID					
Echo Repeater Name					
Platform ID					
Echo Repeater Type					
Time					
Location					
Depth					
Speed					
Heading					
Beam Heading and Vertical Steering Direction					
Echo Repeater Level					
Echo Repeater Level Units					
Calibration Status					
Wavetrain ID for Trigger					
Wavetrain ID of response					
Time Delay					

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Ping Information					
Waveform/Wavetrain Data					
Wavetrain ID	X			X	X[j]
Wavetrain Name					X
Wavetrain Source ID	X			M	
Wavetrain Start Time	X	X			X
Number of Waveforms Forming the Wavetrain	X			X	
For each Waveform:					
Waveform ID	X			X	
Waveform type	X				
Envelope type (Hamming e.g.)	X				
Duration of waveform	X				
Offset Time from start of wavetrain	X				
Amplitude or source level	X				
Source level reference					
Characteristic Frequency 1	X				
Characteristic Frequency 2	X				
Characteristic Frequency 3	X				
Sampled Waveform	X				
Next Transmission					[k]
Event number	X	X		X	
Ping Source ID				X	

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Next Wavetrain				X	
Start Time for Wavetrain	X	X			
Wavetrain Rate				X	
Last ping in sequence notification					
Ping Information – Ping Status					
Source ID				X	
Event Number				X	
Success or Failure Flag				X	
Source Level Measured					
Features Data[l]					
Common					
Feature ID					
Contact or Master Track ID associated with	M	M			
Sensor ID	M	M	X	X	
Platform ID					
Time	X	X			
Command	X	X			
Status	X	X			
Passive					
Bearing	X	X	X		
Bearing Variance	X	X	X		
Bearing Rate	X	X	X		
Bearing Rate Variance	X	X	X		

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Frequency	X	X	M	X	
Frequency Variance	X	X	M		
Frequency Rate	X	X			
Frequency Rate Variance	X	X			
Amplitude/Variance	X	X			
Range	X	X	X		
Range Variance	X	X			
Range Rate	X	X			
Range Rate Variance	X	X			
Speed	X	X			
Speed Variance	X				
Latitude	X				
Longitude	X				
Background level (noise)					
Frequency Jitter					
Frequency Wander					
Signal Duration					
Area of uncertainty (AOU)					
Parameters to describe elliptical areas or hyperbolas if applicable (such as time of arrival at 2 sonobuoys)				X	
Active					
Source ID					X
Ping Event Number					

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Bearing	X		X		X
Range	X		X		X
Speed					X
Heading					X
Amplitude	X				
Background level					
Processing parameters					
Parameters to describe elliptical areas or hyperbolas if applicable (such as time of main blast arrival and return signal in multistatic sonar)					X
Main Blast Information					
Main Blast ID					
Source ID					
Receiver ID					
Ping Event Number					
Time Main Blast Received					
Beam Received On					
Received Energy					
Energy Measurement Accuracy					
Energy Measurement Units					
Peak Amplitude					
Peak Amplitude Units					

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Calibration Status					
Contacts Data					
Data Source/Platform ID/ Operator ID				X	X
Name	X	X		X	X
Contact ID				X	X
Feature and Contact ID's that make up Contact					X
Master Contact/Track ID	M	M		X	X
Classification	X	X		X	X
Confidence Level				X	X[m]
Acceptance					
Time	X	X		X	X
Time of Contact creation or notification					X
Threat	X	X			X
Command	X	X		X	
Status	X	X			
Range Estimate	X	X		X	X
Bearing Estimate	X	X		X	X
Latitude Estimate	X	X		X	X
Longitude Estimate	X	X		X	X
Depth Estimate	X	X		X	X
Speed Estimate	X	X		X	X
Heading Estimate	X	X		X	X

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Area of Uncertainty (AOU)			X		X
Track Data					
Data Source/Platform ID/ Operator ID			M[n]	M	X
Track Name					
Track ID	X	X	X	X	X
Contact/Feature ID's making up the Track			M[o]		X
Classification	X	X	X		X
Battle Space			X		X
Status	X	X			
Command	X	X		X	
Threat	X	X	X		X
Time of Track Creation					
Mode				X	
DQI Level (possible 2 values one for confidence the other for sensor quality/health)			X		X[p]
Time	X	X			X
Speed Estimate	X	X	X	X	X
Heading Estimate	X	X	X	X	X
Longitude	X	X	X	X	X
Latitude	X	X	X	X	X
Longitude Error	X	X	M[q]		X
Latitude Error	X	X	M[q]		X

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Depth			X	X	X
Depth Error			X		X
Acceptance or Confidence Level					[r]
Sonograms					
Receiver ID					
Data type contained					
Time of measurement					
Bearing					
Processing done					
resolution					
Duration					
Frequency reference points for interpreting data					
Data Format					
Data					
Email/Chat Messages					
TBD					
Tactical Information					
Must have:					
Originating Platform/personnel					
Time Stamp					
It may contain some of the following:			X	X	X[s]

Table 6. Data Exchange List Mapped to Other Formats and Systems.

X = maps, M = Modified mapping (as in inexact), ? = possible but may not be intended use, blank = no mapping

Information	STB [a]	IMPACT [a]	Link 11B [b]	OTH Gold [c]	LC2IEDM [d]
Proposed sources/drop areas or positions					
Ping location requests					
Sonobuoy coverage area/pattern					
Allowed RF channels					
Proposed ping schedule and rate					
allocated ping time window					
Stop Pinging Now!					

a. The System Test Bed and IMPACT have the same data server but contain different information since one handles a horizontal towed array while the other processes sonobuoy information. For information on the data server see [16] and [17]
b. For Link 11B see Reference [18]
c. OTH Gold from Reference [19]
d. Private Communication from Anthony Isenor DRDC Atlantic - also see [7].
e. This information could be placed in the context table. This may be reasonable, as the configuration files provide a level of context for the prediction scenario.
f. This may be possible using free text format in a message tag.
g. We must recognize that the position information is associated with the sensor, and not the platform controlling the sensor. Within LC2, this distinction appears to be possible via the holdings table. This table can be used to group platforms and sensors. In this particular case, a sensor would be an individual object item, which could then have an associated platform.
h. Multiple data units are contained within this one table cell: latitude, longitude, and bearing and speed estimates.
i. The LC2 does not actually store the type of positioning, but does store the accuracy associated with the position. In this case, the accuracy would be adjusted according to the type of positioning.
j. The release of a waveform may be considered an action-event within LC2. The details of the waveform do not appear to have a logical storage location within LC2.
k. "Next Transmission" could be considered a request for transmission, or the expected next transmission. If it is a request for transmission, then the action-task table in LC2 may be applicable.
l. The definition between feature and contact is often blurred in the literature. It may be possible to promulgate feature information by using contact messages.
m. There is not this apparent detail in LC2.
n. Sensor identity is most prominent.
o. May be possible by tracking contact and track fusion commands.

p. Data quality and position confidence may not be the same thing. LC2 will store position confidence.
q. Possibly inferred through DQI.
r. Assumed as confidence level on the report of the contact.
s. The exact linkages for actions and request are not clear. However, an action-request could be used to request the movement of an asset to a particular location. The reporting-data table does allow for "plan" reporting. This could potentially be used to plan an object to be at a particular location.

Appendix C - Example Data Value Analysis

In section 2.2 data value was considered for equal partners in an exercise. It is more likely that the partners will be unequal because of equipment/capability differences, or the command is on one platform, or possibly different interests in the operation exist. In such situations the importance of one information type versus another may be different for separate platforms. An example of the information sharing plan between unequal partners is provided below as a framework for handling other scenarios.

C.1 The Scenario

In this example an ASW exercise is considered where there is a surface platform with a horizontal towed array, an MPA deploying sonobuoys and a separately located acoustic source. All platforms share the information described in chapter 2. There is an echo repeater on the target submarine (hereafter referred to as the target).

The surface platform has an environmental modelling capability and a sonar analyst aboard. The horizontal array settings are modified based on environmental information (including any main blast information available that indicates transmission losses and reverberation).

The MPA platform is deploying and monitoring the sonobuoy information. Due to its altitude, its communication with other assets is more reliable than for the other platforms - hence it controls the pings from the source and when the target surfaces between runs, the MPA sets the echo repeater functions. There is no other communication with the target in this operation. The sonobuoy parameters cannot be tuned as the operation proceeds based on environmental data. However interpretation of the sonar returns based on propagation conditions interpreted by the analyst on the surface platform is of use. The MPA is also able to deploy XBT's to gather environment data.

The prosecution of the target is performed by the MPA.

C.2 Analysis of Data Value for the Scenario

An analysis of the information types and their value for the above scenario results in the urgency and priority tables given below. The information shared by the MPA is given in table 7 and for the surface platform in table 8. The scheme presented in these tables is presented as a possible implementation without testing. Future trial results will inevitably cause a revision of the relative priorities and urgencies presented.

Many of the considerations are as discussed in section 2.2. For example when entering the prosecution phase all environmental parameters and acoustic information should be well known, therefore the need to share this information is reduced.

Table 7. Data Value from MPA platform perspective

(What the MPA shares with the surface platform in an ASW operation)

	MUST HAVE	GOOD TO HAVE	NICE TO HAVE
SEARCH AND DETECTION (I)	Sonograms Environmental Data Contact Data Source Information Ping Information Tactical Information	Receiver Information Email/Chat Main Blast Data Feature Data	E/R Information Track Data
LOCALIZATION AND CLASSIFICATION (II)	Environmental Data Contact Data Track Data Tactical Information Source Information Ping Information	Email/Chat Receiver Information Main Blast Data Sonograms Feature Data	E/R Information
PROSECUTION (III)	Source Information Ping Information Track Data Tactical Information	Contact Data	Email/Chat Feature Data Environmental Data Main Blast Data Sonograms E/R Information Receiver Information
POST PROSECUTION	This has elements of both Search and Detection and Localization and Classification		

Increasing Urgency

Decreasing Priority

In the scenario discussed here, tactical, contact, feature and track information are shared with equal priorities between the two platforms so that the combined information can be utilized by both parties. New environmental information must be sent to the platform with the prediction engine and incorporated into the models. The results are shared with the MPA so that it can make use of the propagation conditions in interpreting the sonar signals. Receiver information could be important if data processing depends on its settings. However, since each platform is providing processed data including locations of features etc. the need to exchange receiver information is reduced. Receiver information such as capability, operational status and position may be very important to the commander in deploying and using assets, while it may be of limited importance to other platforms. Source information is important to both platforms so that the bistatic sonar is processed properly. The surface platform needs to receive this information since the MPA is in control of the source. There is no source information to be sent from the surface platform. The same is true for both ping and echo repeater (E/R) information. The echo repeater is a monitor on the experiment that should not affect the ability of the team. It is nice to have but should not be viewed by the operator or tacticians during the experiment since knowledge of it could affect the

Table 8. Data Value from Command Platform Perspective

(What the surface platform shares with the MPA in an ASW operation)

	MUST HAVE	GOOD TO HAVE	NICE TO HAVE
SEARCH AND DETECTION (I)	Environmental Data Contact Data Tactical Information	Email/Chat Feature Data	Source Information Ping Information Main Blast Data E/R Information Sonograms Receiver Information Track Data
LOCALIZATION AND CLASSIFICATION (II)	Environmental Data Contact Data Track Data Tactical Information	Email/Chat Feature Data	Source Information Ping Information Main Blast Data E/R Information Receiver Information Sonograms
PROSECUTION (III)	Track Data Tactical Information	Contact Data	Source Information Ping Information Main Blast Data E/R Information Email/Chat Receiver Information Sonograms Environmental Data Feature Data
POST PROSECUTION	This has elements of both Search and Detection and Localization and Classification		

Increasing Urgency

Decreasing Priority

outcome (it must be used by an independent third party analyzing the experiment outcome). Main blast data is a benefit to the operation. Both platforms receive main blast information individually however the surface platform is the only one that can tune its sonar parameters based on these returns. Therefore, main blast information is only needed by the surface platform. Sonogram interpretation resides on the surface ship - hence the MPA must share it while it is not important for the MPA to receive it in raw form. However, the sonar analyst may choose to Email back important information on the sonograms and other information and collaboration messages will be of use to both parties. During prosecution other information becomes more valuable than email so its priority is reduced.

C.3 Adding a Submarine as a Partner in the ASW Operation

The above scenario and tables have been prepared assuming a constantly open communications link between the platforms. An important consideration is the idea that a platform may not be connected constantly but only on a sporadic basis. This is the case of another submarine operating as part of the team. It will share and receive information only occasionally, such as when surfaced at periscope depth.

In these cases, the information transfer must be prioritized to first receive the most important information for the submarine to continue its mission and then to send the information that may be of most valuable to the team. The possibility of exchange as a team member (in discussions) is limited due to latency of some of the information and by having a limited communication time.

Of greatest importance is receiving information that allows the submarine to operate as an independent platform when it is disconnected from the rest of the team. Thus, ensuring it is on the correct mission is top priority and conveyed through tactical information. Next is the ability to make use of future acoustic pings so source locations and ping schedules must be obtained. It is also reasonable to ensure that the submarine database has a complete list of contacts and tracks by obtaining that information. Features although important could be placed low in the receiving priority only owing to bandwidth considerations and overall transmission time. For a trial it may be important to get new echo repeater settings and, if available, environmental or propagation conditions. Since the chance to discuss 'on-line' may be limited email is low in priority. Other information such as receiver conditions on other platforms and main blast information may be of very limited use and may not be received at all.

Summarizing, the priority for receiving information types in order is:

1. Tactical Information
2. Ping Information
3. Source Information
4. Track Data
5. Contact Data
6. Echo Repeater Information
7. Environmental Information
8. Email
9. Feature Data
10. Sonograms
11. Receiver Information
12. Main Blast Data

For sending information the requirements are driven by what is most important to the team on the surface. In this case, tactical information is still of highest importance. Next is sending information on tracks and contacts that may enhance the other team platform's knowledge. Thus, the priority in sending information is as follows:

1. Tactical Information
2. Track Data

3. Contact Data
4. Environmental Information
5. Main Blast Data
6. Email
7. Echo Repeater Information
8. Receiver Information
9. Feature Data
10. Sonograms
11. Source Information (however there is no source controlled by the submarine)
12. Ping Information (since no source control no ping information is available)

It may be the team will benefit more from information sent from the submarine than for the submarine receiving environmental information. Hence the sending of data could be interspersed with receiving data. In which case, the tactical information needs to be exchanged then information for the submarine to have the capability to process the sonar signals properly so it can provide accurate information the next time it transmits (source and ping information used to form contacts and tracks). This could be followed by giving the team contact and track information to compile the COP then for the submarine to receive the contact and track updates. With these sort of considerations, from the submarine's perspective the transmission sequence may be as presented in table 9.

Table 9. Data Transmission Priority by Participating Submarine

SEQUENCE	INFORMATION TYPE	TRANSMISSION MODE
1	Tactical Information	Send
2	Tactical Information	Receive
3	Ping Information	Receive
4	Source Information	Receive
5	Track Data	Send
6	Contact Data	Send
7	Track Data	Receive
8	Contact Data	Receive
9	Echo Repeater Information	Receive
10	Environmental Information	Send
11	Environmental Information	Receive
12	Main Blast Data	Send
13	Email	Receive
14	Email	Send
15	Echo Repeater Information	Send
16	Receiver Information	Send
17	Feature Data	Send
18	Feature Data	Receive
19	Sonograms	Receive
20	Sonograms	Send
21	Main Blast Data	Receive
22	Receiver Information	Receive
23	Ping	Send (N/A)
24	Source	Send (N/A)

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Initialisms

AGC	Automatic Gain Control
AOU	Area Of Uncertainty
ASW	Anti-Submarine Warfare
A/SWC	Antisubmarine Warfare Commander/Coordinator
COP	Common Operating Picture
CPU	Computer Processing Unit
CW	Continuous Wave (usually a sine wave)
E/R	Echo Repeater
FM	Frequency Modulated (usually a waveform that sweeps frequencies)
GPS	Global Positioning System
IMPACT	Integrated Multistatic Passive Active Concept Testbed
IP	Internet Protocol
LC2IEDM	Land Command and Control Information Exchange Data Model
MPA	Maritime Patrol Aircraft
NUW	Networked Underwater Warfare
STB	System Test Bed
TACNAV	Tactical Navigator
TDP	Technology Demonstration Project
TIAPS	Towed Integrated Active Passive Sonar
TMA	Target Motion Analysis
UWW	UnderWater Warfare
AESS	Allied Environmental Support System
EMM	Environmental Modelling Manager
LOP	Local Operating Picture
MOSIC	Maritime Operational Surveillance and Information Centre
RMP	Recognized Maritime Picture
XBT	eXpendible Bathy-Thermograph

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It is widely assumed that sharing information between individual platforms using tactical networks will improve the accuracy of the Common Operating Picture (COP). This interest is based on the belief that task group effectiveness increases with the amount of shared information. This is true only if the information exchange requirements are carefully considered. Not only is the correct information required at the right time but the weight in importance of one information type versus another must be considered when allocating communication resources. The scope here has been limited to the formation of the Underwater Picture in an Anti-Submarine Warfare (ASW) scenario.

The information content requirement is addressed with the definition of twelve types of information, each described in detail. This information contains tactical command and control type information as well as sensor information used to process sonar signals and form the COP. The detail goes beyond the present command and control data available in existing communications like Link 11 and OTH Gold. Instead, an IP based network with information push-pull capability is envisioned. This network will operate with a limited bandwidth in Defence R&D Canada – Atlantic's Networked Underwater Warfare Technology Demonstration Project. So, rather than transmitting everything, careful choices must be made and priorities and urgency must be considered. An analysis of an ASW operation is presented showing the relative importance of the data and how the importance changes with the phase of the operation.

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